

# Late Wisconsinan Deglaciation Styles of Parts of the Contoocook, Souhegan, and Piscataquog Drainage Basins, New Hampshire

By Carol T. Hildreth and Richard Bridge Moore

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Pembroke, New Hampshire  
1996

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## PREFACE

Dear Friends,

It is our pleasure to welcome you to Concord, New Hampshire (fig. A), for the 56th Annual Reunion of the Friends of the Pleistocene. The last time the Friends gathered in this region was in 1981 (44th reunion headquartered in Leominster, Mass.) when Carl Koteff and Byron Stone had us visit the Pleistocene of the Nashua River Basin. During that trip, the Friends visited valley-train deposits in the Squannacook River (tributary to the Nashua) in the Townsend quadrangle, Massachusetts - New Hampshire, (southeast corner of the area covered by the current field trip). Meltwater draining Glacial Lake Souhegan carved deep channels in bedrock and till below the spillway and contributed abundant materials to that valley train.

The last time the Friends met in New Hampshire was in 1977 (40th reunion, in Conway) when Bob Newton demonstrated evidence for the Pleistocene in the Ossipee 15-minute quadrangle.

This guidebook describes the deglaciation style of, and evidence for, a series of glacial lakes in the Contoocook, Souhegan, and Piscataquog River basins. Several accessible locations (fig. B) will be visited that demonstrate the glacial lake deposits, proximity of the receding ice front, outlets, and erosional channels; directions of glacial movement, and a glacial readvance site. This guidebook represents "WORK IN PROGRESS;" data are not comprehensive and are detailed only in a few areas at this time. We have put together as complete a picture as we can to date and welcome your contributions, alternative interpretations, and overall discussion. Please feel free to offer your opinions, experience, and suggestions for further investigations.

We have a lot to show you and much ground to cover. Because the bus is too large for some routes, we have gone the "long way 'round" in some places. We request your cooperation in moving on quickly when requested to do so. On both days, we will be leaving promptly at 8 AM from the Hampton Inn Parking Lot.

Thanks for your cooperation! ENJOY YOUR TRIP!!!

Carol T. Hildreth and Richard Bridge Moore

## ACKNOWLEDGEMENTS

The authors thank Eugene L. Boudette, New Hampshire State Geologist, for funding the surficial mapping of the Federal-State Cooperative Geologic Mapping (COGEOMAP) program and Carl Koteff, U.S. Geological Survey, for coordinating this program and for spending many days in the field mapping with the authors.

Special thanks go to Dr. Donald H. Chapman, Geology Professor Emeritus at the University of New Hampshire, who specializes in geomorphology. Dr. Chapman's career as a professor, from the early 1930's through 1974, was dedicated to his students. The junior author is one of hundreds of his students who greatly appreciate his dedication.

The following people have generously contributed their time and expertise to the logistics of the trip: Susan Tufts-Moore helped with the banquet planning and especially with Friday evening's slide show preview of this year's trip. Richard W. Hildreth designed and drafted the cover illustration and provided unflagging support toward completion, of this guidebook.

We are especially delighted that long-time Friends of the Pleistocene, Dr. Donald H. Chapman and Dr. Charles S. Denny, were able to join us at the banquet.

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By Carol T. Hildreth, *New Hampshire State Geologist's Office*, and Richard Bridge Moore

Friends of the Pleistocene 56th Annual Reunion Guidebook 1993

**Day 1, Saturday, May 22, 1993**

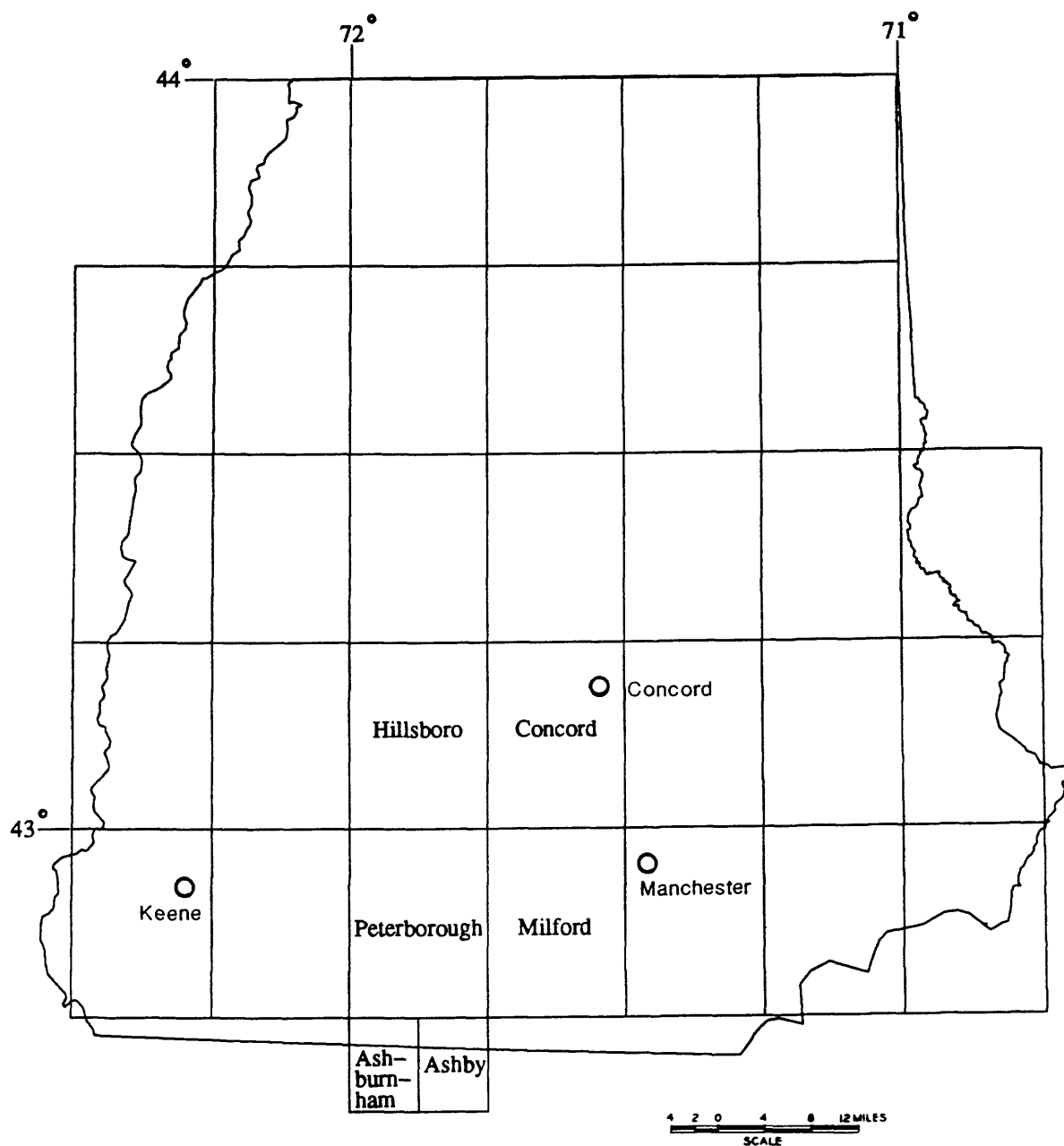
## **Souhegan and Contoocook Drainage Basins**

The purpose of the trip on Day 1 (figs. 1 and 2) is to provide an overview of the general topography, geology, and deglaciation styles of the area, in particular for the Souhegan and Contoocook drainage basins, both of which have major modern segments that drain northward. These basins are separated by the north-northeast-trending Wapac Range, so-named by the combining of the names of its end members: Watatic Mountain at the south in Ashburnham, Mass., and Pack Monadnock Mountain at the north in Greenfield N.H. (Pack comes from an Indian word meaning "little"). Geographically the range extends northeastward and then eastward as Winn Mountain, Lyndeborough Mountain, and the Piscataquog Mountains. Various notches in these mountains provided southward and then eastward outlets for glacial meltwater that drained the Souhegan and Contoocook valleys. The earliest stages of glacial Lake Contoocook drained into the headwaters of the Millers River and thence to the Connecticut River. The earliest stages of glacial Lake Souhegan drained into the Squannacook River, a tributary of the Nashua River, which flowed into the Merrimack River. Later stages of glacial Lake Souhegan flowed into the Nissitissit River and then into the Merrimack (Koteff, 1970). Intermediate stages of the Contoocook drained southeastward through Russell Station down Stony Brook to the Souhegan valley, thence to the Merrimack. Later stages drained eastward and then southward into the Piscataquog valley and on into the Merrimack.

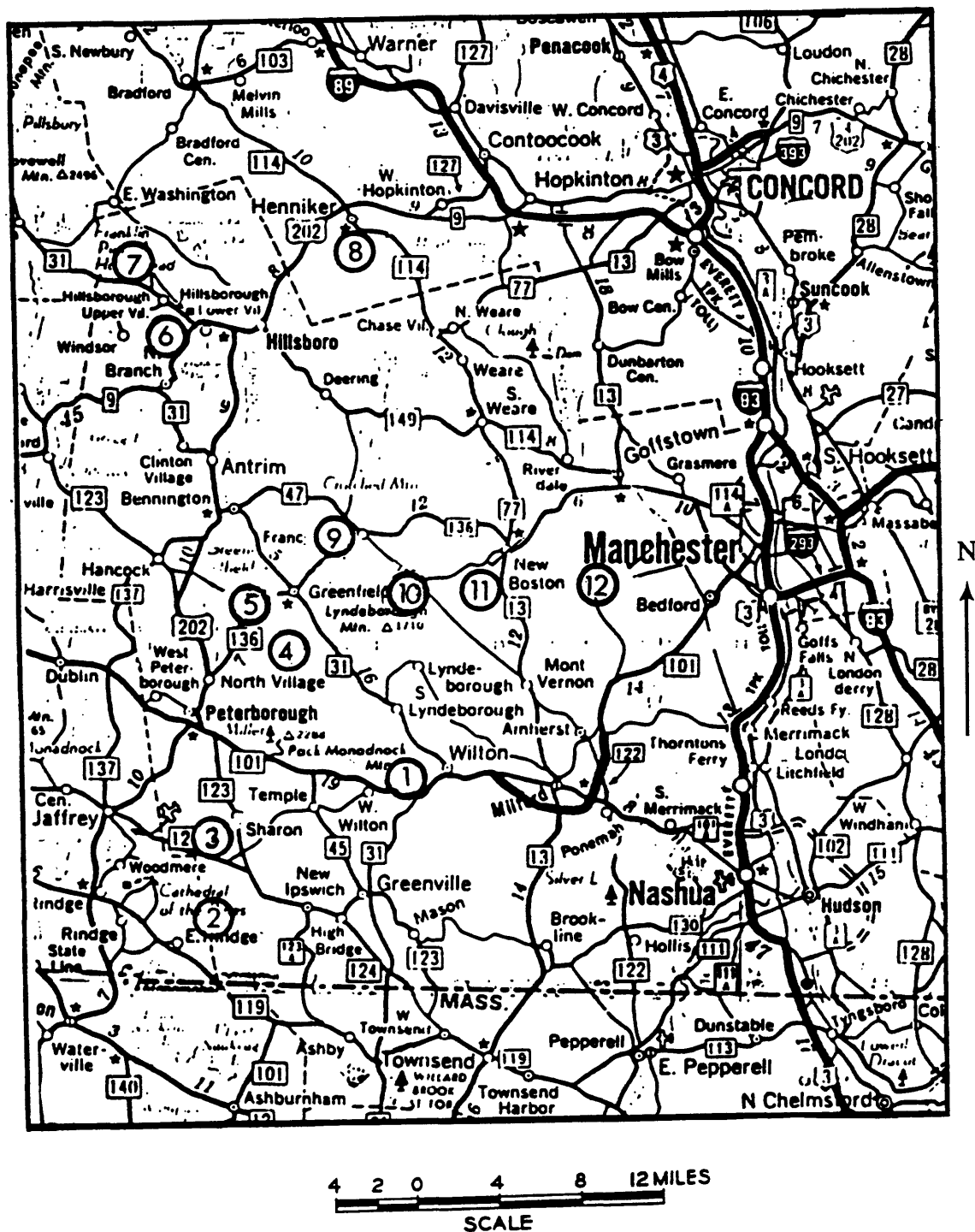
We will examine features that are associated with these glacial lakes, such as deltas, lake-bottom deposits, ice-contact deposits, and lake outlet channels. Some outlets, especially those at stops 4 and 8, indicate that severe erosion resulted from floods associated with the breaching of the glacial ice dams that earlier had formed the lakes, whereas other outlets, such as the one near stop 5, indicate much smaller flows (Moore, 1995).

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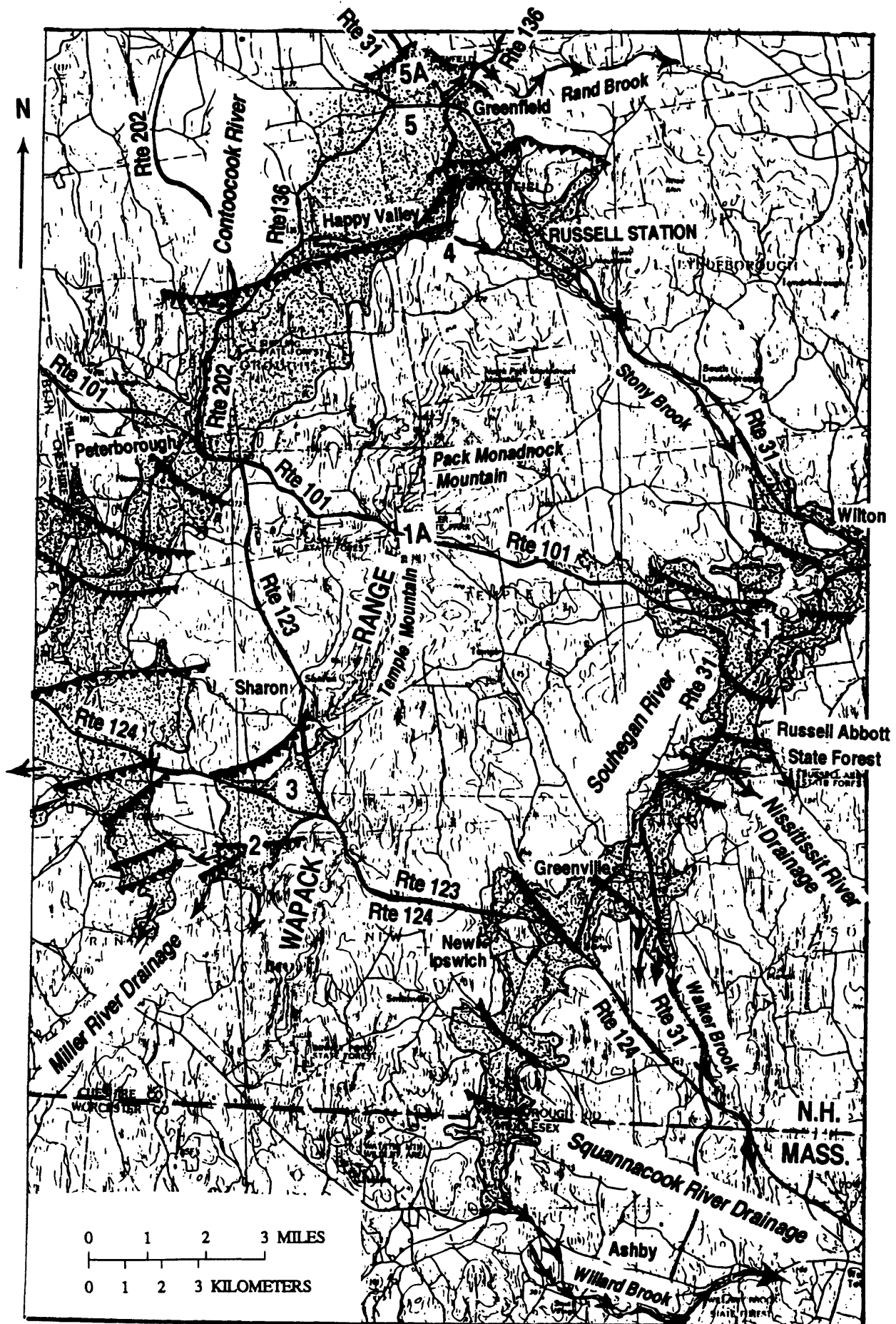
Note to future users of this guidebook: Those who may retrace our steps should know that it is **absolutely essential** to get permission from pit owners to enter their property. Some owners may be reluctant to grant permission. Also the following road log is designed for buses, and in places, there are shorter routes that could be used by cars.



**Figure A.** Quadrangles covered by the 1993 Friends of the Pleistocene field trip in New Hampshire. The Peterborough 15' quadrangle is now subdivided into the PeterboroughNorth, PeterboroughSouth, Greenville, and Greenfield 7-1/2' quadrangles. The Hillsboro 15' quadrangle is now subdivided into the Hillsboro Upper Village, Hillsboro, Deering, and Henniker 7-1/2' quadrangles. The Concord 15' quadrangle is now subdivided into the Hopkinton, Weare, Goffstown, and Concord 7-1/2' quadrangles. The Milford 15' quadrangle is now subdivided into the New Boston, Milford, South Merrimack, and Pinardville 7-1/2' quadrangles. (The above listed 7-1/2' quadrangles start in the northwest quadrant of the 15' quadrangle and are listed counterclockwise.) Also included are the Ashby and Ashburnham, Massachusetts

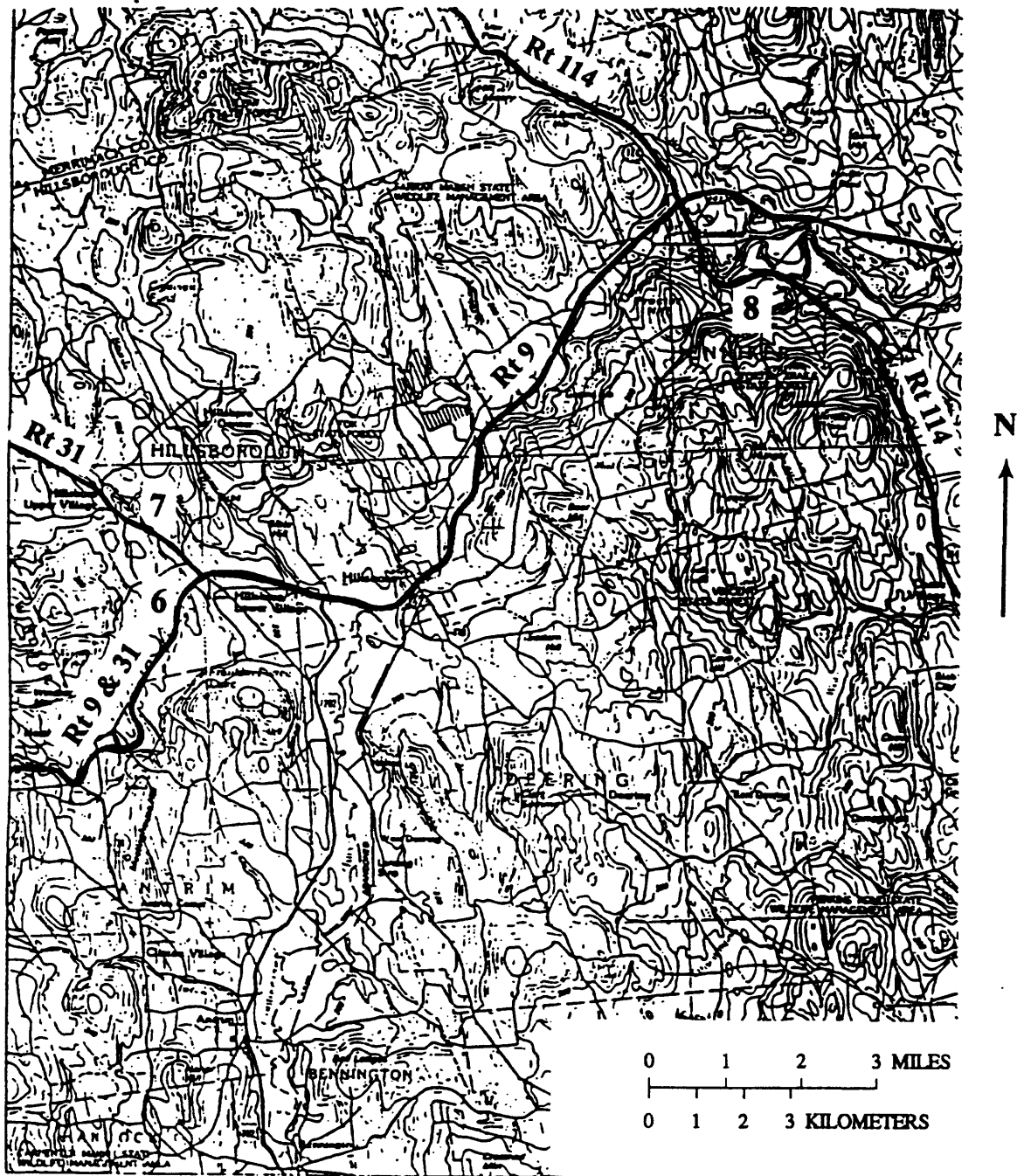


**Figure B.** Location of stops, Days 1 and 2, 1993 Friends of the Pleistocene field trip in the Contoocook, Souhegan, and Piscataquog drainage basins, New Hampshire.



**Figure 1.** Topographic map showing Day 1 Stops 1 through 5 in the Souhegan and Contoocook drainage basins. Generalized ice-frontal positions, outlets, and rough shorelines of various stages of glacial Lakes Souhegan and Contoocook are sketched on for purposes of discussion. Base from U.S. Geological Survey, Lowell, Mass.-N.H., 1:100,000, 1988.





**Figure 2.** Topographic map showing Day 1 Stops 6 through 8 in the Contoocook drainage basin. Base from U.S. Geological Survey, Concord, N.H., 1:100,000, 1988.

## **ROAD LOG**

**Day 1, Saturday, May 22, 1993**

### **Cumulative mileage (with mileage between stops)**

- 0.0 (0.0) Hampton Inn, Bow, N.H.—Located on a stream terrace that was cut into sediments of glacial Lake Hooksett, which once inundated this part of the Merrimack River valley. Turn left (south) out of the parking lot.
- 0.3 (0.3) Take Interstate 89 south to Interstate 93.
- 0.5 (0.2) Take Interstate 93 south.
- 0.7 (0.2) Now climbing out of glacial lake area.
- 5.2 (4.5) Descend back into glacial Lake Hooksett.
- 5.3 (0.1) Southwardly dipping deltaic foreset beds can be viewed in an exposure to the left (east). Located behind the delta are clay pits on the east side of the river valley.
- 6.1 (0.8) The bedrock ridge to the right (west) is the first of two ridges associated with the Campbell Hill fault zone.
- 6.7 (0.6) The second bedrock ridge associated with the Campbell Hill fault is described on the interim New Hampshire State bedrock map as a high-angle normal or reverse fault (Lyons and others, 1986).
- 7.4 (0.7) Toll booth. Go straight down the highway on Interstate 293 (left lanes).
- 10.6 (3.2) The top of the delta to the left (east) was built out into glacial Lake Merrimack. glacial Lake Merrimack was one of three glacial lakes that formed in this part of the Merrimack valley during deglaciation. The other two were glacial Lake Hooksett to the north and glacial Lake Tyngsborough to the south (Koteff and others, 1984).
- 12.6 (2.0) The deposit to the right (west) is part of a large delta that formed where the Piscataquog River once flowed into glacial Lake Merrimack. The surface is much higher now because the area is used for the Manchester landfill.
- 13.2 (0.6) Cross Black Brook.

- 13.9 (0.7) Amoskeag Falls to the left (east), where the Merrimack River has eroded down through the deposits of glacial Lake Merrimack to bedrock. The falls were used in the past as a source of power for the mills of Manchester, and they still are used to generate electricity.
- 14.0 (0.1) The Mobil gas station to the right (west) is just south of the site of an archeological dig for Indian artifacts in 1985. Amoskeag Falls was a focal point for Indian gatherings, especially during May when salmon and other anadromous fish could be caught here easily as they attempted to swim upstream.
- 14.7 (0.7) The mills here were built with bricks that were made from the clay deposited in glacial Lake Hooksett. The bricks were transported downstream to Manchester on barges along the old canal system.
- 15.4 (0.7) Cross the Piscataquog River.
- 17.8 (2.4) Exit onto Route 101 west.
- 19.8 (2.0) At the light, turn left and continue west on Route 101.
- 20.2 (0.4) At the shoreline of glacial Lake Merrimack, the Bedford Village Inn on the right (northwest) would have been lakefront property about 14,000 years ago.
- 20.6 (0.4) Clay deposited in glacial Lake Merrimack was used to make bricks. The mills in Lowell, Mass., were built from bricks that were made in Bedford and transported down the Merrimack River on the old canal system. Behind the farmhouse to the right is a 200-year-old brick-ended house, no doubt made with bricks from glacial Lake Merrimack clay deposits.
- 21.2 (0.6) The road descends into what was an embayment of glacial Lake Merrimack.
- 22.1 (0.9) The road ascends back out of the embayment.
- 25.1 (3.0) Cross Pulpit Brook, which is in another embayment of glacial Lake Merrimack. Pulpit Brook is at an elevation here that was once 10-20 feet below the glacial lake surface. We are about 4 miles downstream from what will be our last stop on the field trip on Day 2 (Sunday).
- 32.2 (7.1) Cross the Souhegan River and flood plain.
- 32.6 (0.4) Notice prominent bedrock roadcuts at road exit.
- 36.7 (4.1) Very coarse grained stratified drift is visible on both sides of the road.
- 37.7 (1.0) Intersection of Routes 101 and 101A west of downtown Milford, N.H. Turn left at second light and continue west on Route 101.

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## OPTIONAL SIDE TRIP

39.8 (2.1) Take right onto Route 31 through downtown Wilton.

40.1 (0.3) Take left on Route 31 in downtown Wilton and go up the V-shaped valley of Stony Brook, which was carved partly, through bedrock and partly through earlier glacial lake deposits, by meltwater draining southeast from Lyndeborough, Russell Station, and the Greenfield area (related to Stop 4).

Location of stops, Days 1 and 2, 1993 Friends of the Pleistocene field trip in the Contoocook, Souhegan, and Piscataquog drainage basins, New Hampshire. by meltwater draining southeast from Lyndeborough, Russell Station, and the Greenfield area (related to Stop 4).

41.6 (1.5) Turn around at intersection; return to Route 101 by same route.

43.5 (1.9) Turn right onto Route 101 west.

## END OPTIONAL SIDE TRIP

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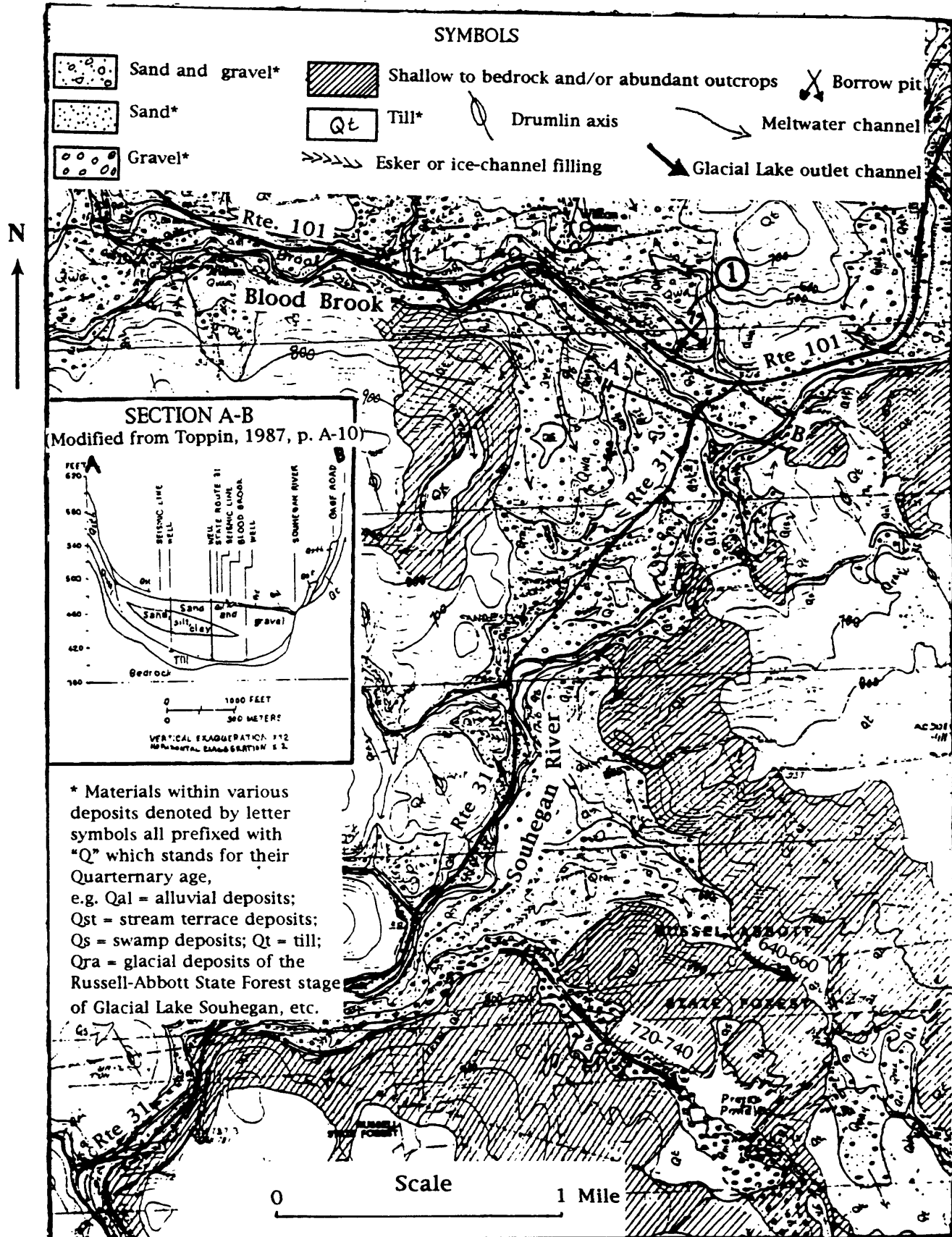
44.3 (0.8) Cross Souhegan River. Highway was built on stream-terrace deposits.

45.0 (0.7) Waterworn bedrock surface on south side of road near intersection with side street.

45.5 (0.5) Junction of Routes 101 and 31. Stay on Route 101.

45.8 (0.3) STOP 1. Gravel pit entrance on right (north). Park in parking lot of business and/or gas station on opposite side of road and walk up into pit (or drive into pit, approximately 0.1 mile in and out). Bus should park outside of pit and off road to left (south). (Parking on the side of the road is dangerous here because of the blind curve.) **BE CAREFUL WALKING ACROSS THE ROAD!!!**

Pit contains deposits of esker and deltaic topset, foreset, and bottomset beds of a middle stage of glacial Lake Souhegan (Russell-Abbott State Forest outlet at elevation 640-660 feet). Some of the bottomset beds might be characterized as proximal varves. A recumbent fold of bottomset beds on the margin of the delta, faulting, and the presence of irregular lenses of till(?) may indicate glacial readvance. Another pit in similar deposits at about the same elevation across Blood Brook is visible through the trees. We infer here that these deposits were originally continuous and that, subsequent to the lowering of glacial Lake Souhegan, Blood Brook cut down through them. The lowest swale that one sees when standing in the pit looking south toward the distant hills is the 640-660 feet Russell-Abbott State Forest outlet of glacial Lake Souhegan (fig. 3).



**Figure 3.** Surficial geologic map showing location of Stop 1 in deltaic and bottomset beds of Russell-Abbott State Forest stage of glacial Lake Souhegan (outlet elevation is 640-660 feet), Wilton, N.H. Cross section shows some clay at depth in the valley. Base from U.S. Geological Survey, Greenville, N.H., 1:24,000, 1987.

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## ALTERNATIVE ROUTE TO NEXT STOP

- 45.9 (0.1) Assuming we have driven into the pit, exit left (east) onto Route 101.
- 46.2 (0.3) Turn right onto Route 31 south toward Greenville. Route 31 is a scenic route through the valley of the north flowing Souhegan River.
- 46.4 (0.2) Blood Brook crossing (called Gambol Brook on road sign).
- 46.45 (0.05) Entrance on the right (west) to another pit in materials that are equivalent to those of Stop 1 (through part of a junkyard).
- 47.25 (0.08) Slumped pit on right.
- 47.4 (0.2) Slumped pit uphill in woods on right (west), where bottomset beds sometimes are visible from the highway.
- 48.0 (0.6) Pit on right (west) contains coarse-grained ice-contact deposits that are overlain by bottomset beds of glacial Lake Souhegan. (This is a potential stop if exposures are good during day of trip.)
- 49.2 (1.2) Cross Souhegan River.
- 50.2 (1.0) Gorge of Souhegan River is down to the right (west) in valley below (not visible from road).
- 51.2 (1.0) Turn right (west) on to iron bridge.
- 51.9 (0.7) Stop sign. Go straight through downtown Greenville.
- 52.15 (0.25) Take Route 123 north on right (west) toward New Ipswich.
- 53.8 (1.65) Go right (west) onto Routes 124 west and 123 north at High Bridge, where the Souhegan River passes through a deep gorge and flows northward. Scattered glacial lake deposits in the valley in this area were laid down when the outlet of glacial Lake Souhegan was at an elevation of 1040-1050 feet in Ashby, Mass., about 4.4 miles south of here, where glacial meltwaters carved the scenic gorge of Willard Brook (fig. 1).
- 55.2 (1.4) New Ipswich town center. Continue on Routes 124 west and 123 north. Clay deposits underlie the town center at depth.
- 56.8 (1.6) Outlet at 1260-1280 feet elevation for meltwater that was responsible for kame-terrace deposits just to the right (north).

58.2 (1.4) Windblown Gap Ski Area entrance. Cross Wapack Range and enter Contoocook drainage basin.

58.8 (0.6) Turn left onto Route 124 west.

59.05 (0.25) Turn left onto Timbertop Road (second left after Routes 124 and 123 separate).

**END OF ALTERNATIVE ROUTE** (if you followed this one, you will have to adjust your cumulative mileage on the rest of the trip).

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### **Get back in vehicles and head west on Route 101**

47.0 (1.2) Wilton Center Road on right. (An ice-channel filling in the woods on the hilltop to the right (north) parallels the road for almost one-half mile.)

52.2 (5.2) **Stop 1A.** Nearly at crest of divide. Stop at bedrock outcrop just after "Road Narrows" sign on right. **BEWARE OF SOFT SHOULDER! KEEP AT LEAST ONE WHEEL ON THE PAVEMENT.** Glacial striations here trend S. 57-72° E., which indicates that glacial flow was diverted 20-40° more eastward through this notch as compared to the general southeastward flow in the region. Striations are found on rusty-weathering pelitic schist and metasandstone of the upper part of the Silurian Rangeley Formation (Lyons and others, 1986). Also, in the woods to the right (north) is a meltwater channel associated with deposits just west of the divide (fig. 4). **Look carefully. These striations are faint.**

52.3 (0.1) Temple Mountain Ski Area parking lot on left (south).

### *DRAINAGE DIVIDE BETWEEN SOUHEGAN AND CONTOOCCOOK BASINS*

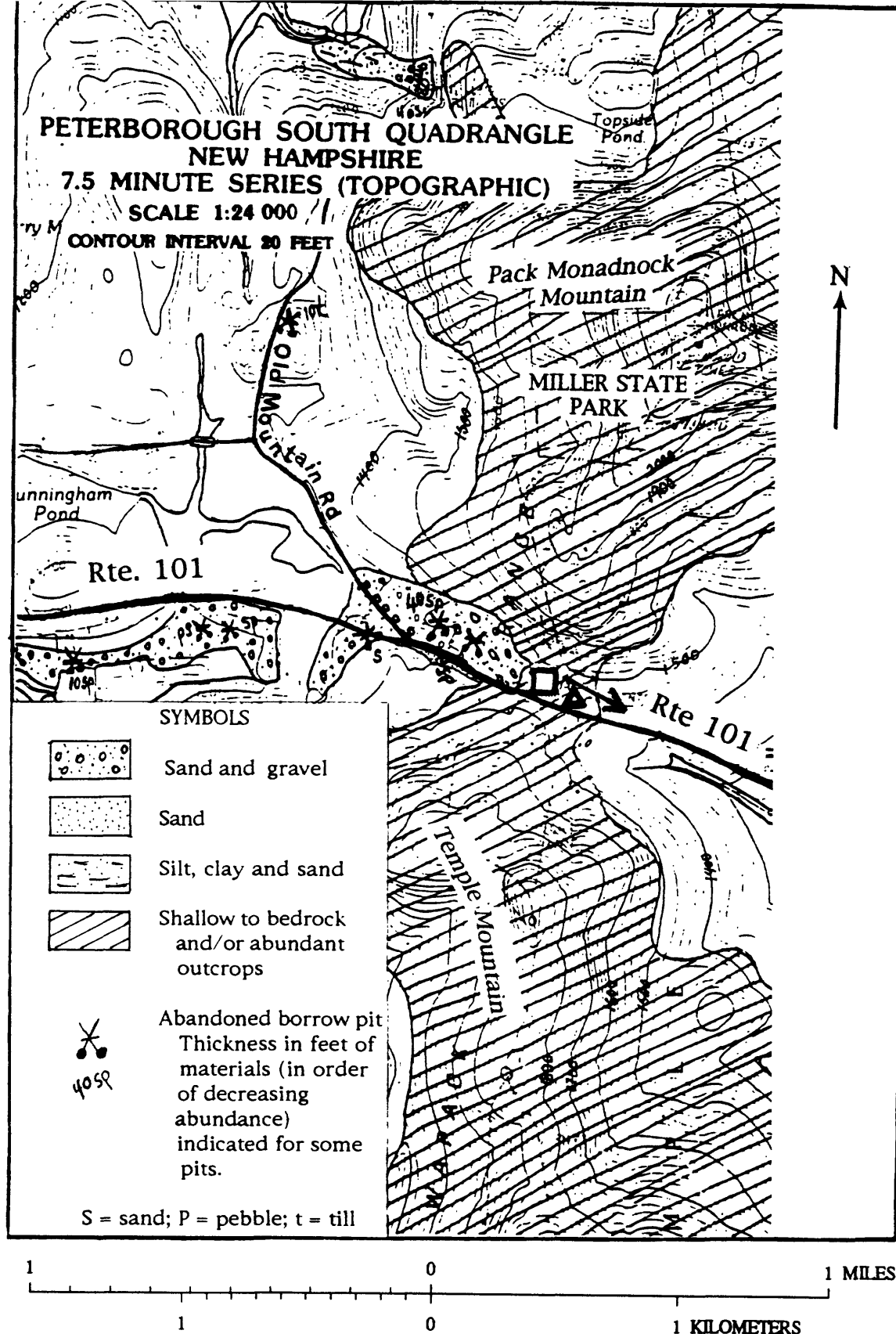
52.5 (0.2) Miller State Park on right (north). A paved road to the top of Pack Monadnock Mountain affords spectacular views of the entire region. The parking lot at the bottom entrance partly fills the outlet channel for glacial meltwater that laid down a small sand deposit west of the divide at the intersection of Old Mountain Road and Route 101 (fig. 4).

52.8 (0.3) Old Mountain Road on right (north). Also to the right in the woods is an overgrown pit in the sand deposits that are graded to the spillway of the parking lot of Miller State Park, (fig. 4). **SPECTACULAR VIEW OF MONADNOCK MOUNTAIN DIRECTLY AHEAD!!**

53.8 (1.0) Till roadcut on right (north).

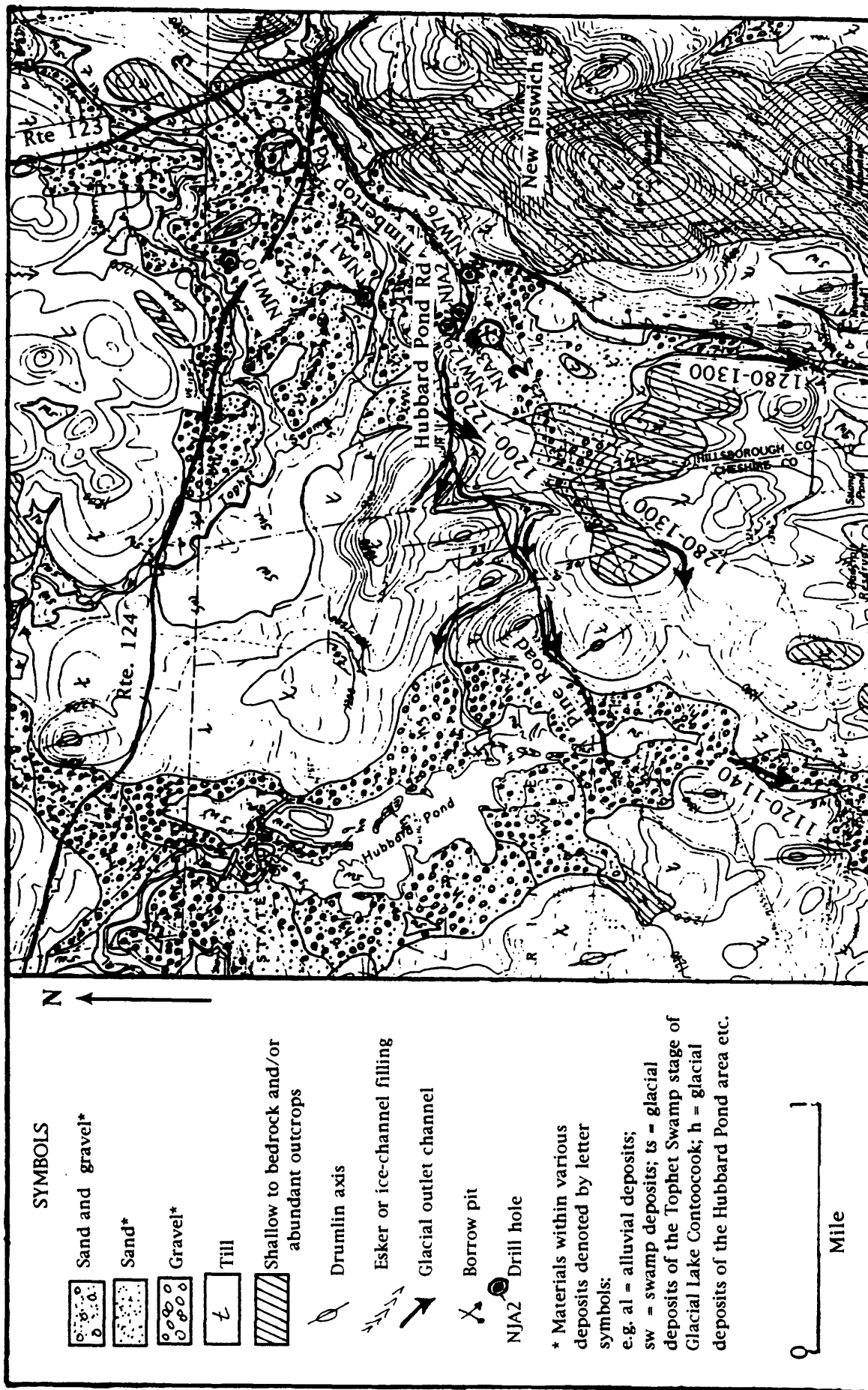
55.4 (1.6) Turn left onto Route 123 south toward Sharon.





**Figure 4.** Surficial geologic map showing location of Stop 1A (triangle) near the divide between Temple Mountain on the south and Pack Monadnock Mountain on the north. A small ice-contact deposit on the west side of the divide is graded to the swale in the parking lot of Miller State Park (square). Arrow at Stop 1A shows general direction of glacial striae. Base from U.S. Geological Survey, Peterborough South, N.H., 1:24,000, 1987.

- 56.4 (1.0) Outcrops on the right (west) have recently exposed and clearly visible striations.
- 59.3 (2.9) SHARON ARTS CENTER ON RIGHT--GREAT LOCAL CRAFTS ON DISPLAY. Worth visiting!
- 60.9 (1.6) Temple Glass Factory historic marker on left. Apparently, some of the glacial sand deposits in the Temple area were used to make glass.
- 61.7 (0.8) Turn right onto Route 124 west.
- 61.95 (0.25) Turn left (south) onto Timbertop Road (second left after intersection of Routes 123 and 124).
- 62.6 (0.65) Turn right at fork onto Hubbard Pond Road.
- 64.1 (1.5) **STOP 2.** Park at entrance to pit; do not drive into pit. Walk left (south) into entrance. Glacial outwash deposits completely filled the basin here between the glacial front and a till-floored outlet at an elevation of 1,280-1,300 feet, to the south. Following this, the ice margin receded and drainage was redirected to a till-bedrock-floored notch at an elevation of 1,280-1,300 feet, to the west. Deposits here are relatively fine grained distal sands, some gravel, and silt. Esker(s) just to the north could have been active while these sediments were being deposited. Return to vehicle and continue west on Hubbard Pond Road (fig. 5).
- 66.5 (2.4) Cross inconspicuous outlet channel (1,200-1,220-foot elevation) for glacial meltwater that deposited materials that are slightly younger than those at the last stop. Meltwater flowed to the left (southward) here.
- 66.7 (0.2) Turn left (southwest) onto Pine Road. In the next one-half mile, the road crosses conspicuous stretches of a glacial outwash channel that was carved in till and is occupied now by swamps, meadows, and an underfit stream.
- 66.8 (0.1) Cross the outwash channel. Flow is to right (north).
- 66.9 (0.1) Cross the outwash channel. Flow is to left (south)
- 67.2 (0.3) Cross the outwash channel. Flow is to right (north). From here, the road follows the north bank of a segment of the outwash channel that was subsequently abandoned when the north-draining channel at the last road crossing was eroded. The meltwater that formed these channels joined south-flowing meltwater and contributed material to the deposits of the Hubbard Pond area. At Hubbard Pond, the deposits were graded southward to a till-bedrock gap at an elevation of 1,120-1,140 feet, about 1 mile southwest of here. (All of the above channels and outlets are shown in figure 5.)



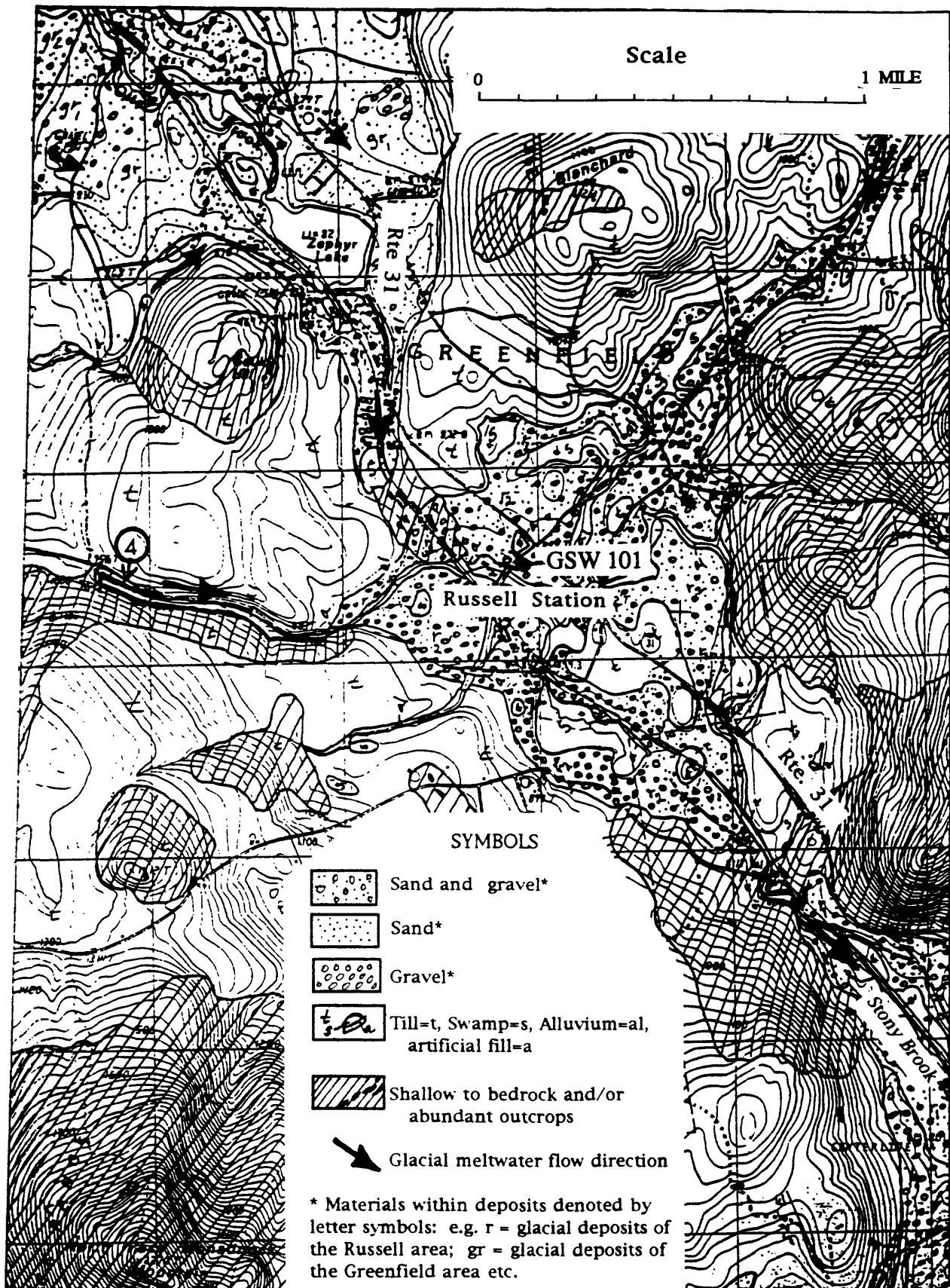
**Figure 5.** Surficial geologic map showing location of Stops 2 and 3 in the Contoocook drainage basin in the vicinity of New Ipswich, N.H. Arrows indicate the major outlets for glacial meltwater associated with several different deposits. Drill-hole data are given in appendix A. Base from U.S. Geological Survey, Peterborough South, N.H., 1:24,000, 1987.

- 68.2 (1.0) Turn around in gravel pit on left. These deposits are coarse-grained pebble to cobble gravels that form the head of outwash for one of the south-graded sequences mentioned in the preceding paragraph.
- Retrace route along Pine Road.
- 69.7 (1.5) Turn right (east) onto Hubbard Pond Road.
- 70.8 (1.1) Intersection and stop sign. Continue straight and go back to Route 124.
- 71.4 (0.6) At stop sign, turn left (west) onto Route 124.
- 71.65 (0.25) **STOP 3.** Turn right (north) into New Ipswich Town Landfill. Drive around perimeter of pit, counterclockwise. This pit has a WEALTH OF GLACIAL PHENOMENA; here are a few (fig.5).
- 71.9 (0.25) Diamicton over striated bedrock.
- 80.0 (0.1) Eskers.
- 80.2 (0.2) Foreset beds of coarse-grained sand and pebble gravel.
- 80.3 (0.1) Leave pit. Turn left (east) onto Route 124.
- 80.8 (0.5) Turn left (north) onto Route 123 north.
- 81.6 (0.8) Great view to northeast shows Temple Mountain, part of north-northeast-trending Wapack Range.
- 83.2 (1.6) Sharon Arts Center again.
- 87.0 (3.8) Intersection with Route 101. Turn left (west) toward Peterborough (Routes 123 north and 101 west). View of Monadnock Mountain ahead.
- 87.8 (0.8) Turn right onto Routes 202 north and 123 north toward Greenfield State Park. Contoocook River parallels road on left and flows northward.
- 88.5 (0.7) Downtown Peterborough on left (west). Continue north on Routes 202 and 123.
- 90.2 (1.7) Turn right (northeast) onto Route 136 east toward Greenfield. Contoocook River to the left (west) flows northward.
- 91.9 (1.7) Turn right (east) onto Happy Valley Road toward Happy Valley School.
- 92.1 (0.2) Turn right (south) at fork and stay on paved road.

- 93.2 (1.1) Turn left (east) onto Old Greenfield Road.
- 93.65 (0.45) Pavement ends but keep going straight.
- 94.6 (0.95) **STOP 4.** Road intersection at 955-foot elevation. Park on side of road. Walk east on road about 0.2 mile. The bedrock gorge along the right (south) side of the road served as the outlet channel for the 955-960-foot stage of glacial Lake Contoocook (fig. 6). Meltwater going down this channel contributed coarse-grained deposits to the Russell area and thence flowed southeast through Lyndeborough and the valley of Stony Brook to Wilton, Milford, and the Souhegan outwash. This is interpreted as the site of a jokulhlaup, a glacier outburst flood (Moore, 1995).

**Return to vehicle and turn left at intersection so as to go north toward Greenfield.**

- 95.2 (0.6) Small pond at right (east) lies in the channel of the next lowest outlet (860-880-foot elevation) of glacial Lake Contoocook. Here, meltwater flowed eastward and then southward into the Russell area and possibly contributed to deposits south of Zephyr Lake, before it continued southward to Stony Brook and the Souhegan valley (fig. 6).
- 95.6 (0.4) Stop sign. Go straight ahead onto paved road.
- 96.4 (0.8) Railroad crossing.
- 96.9 (0.5) Turn left (west) onto Route 136. This is downtown Greenfield.
- 97.0 (0.1) Intersection with Route 31 north on right, but go straight on 136 west.
- 97.1 (0.1) Swale in road just beyond downtown Greenfield is outlet channel for glacial Lake Contoocook at 820-840-foot elevation stage.
- 97.5 (0.4) Railroad crossing.
- 97.7 (0.2) Take right (west) fork toward Greenfield State Park. In 0.1 mile, pass park entrance on right (north).
- 97.9 (0.2) Oak Park, Town of Greenfield's public park on left. LUNCH STOP! Return to Route 136 after lunch.
- 98.1 (0.2) Turn right (east) onto Route 136.



**Figure 6.** Surficial geologic map showing gorge at Stop 4 that was carved by meltwater of the 955-960-foot spillway elevation of glacial Lake Contoocook. Base from U.S. Geological Survey, Greenfield, N.H., 1:24,000, 1987.

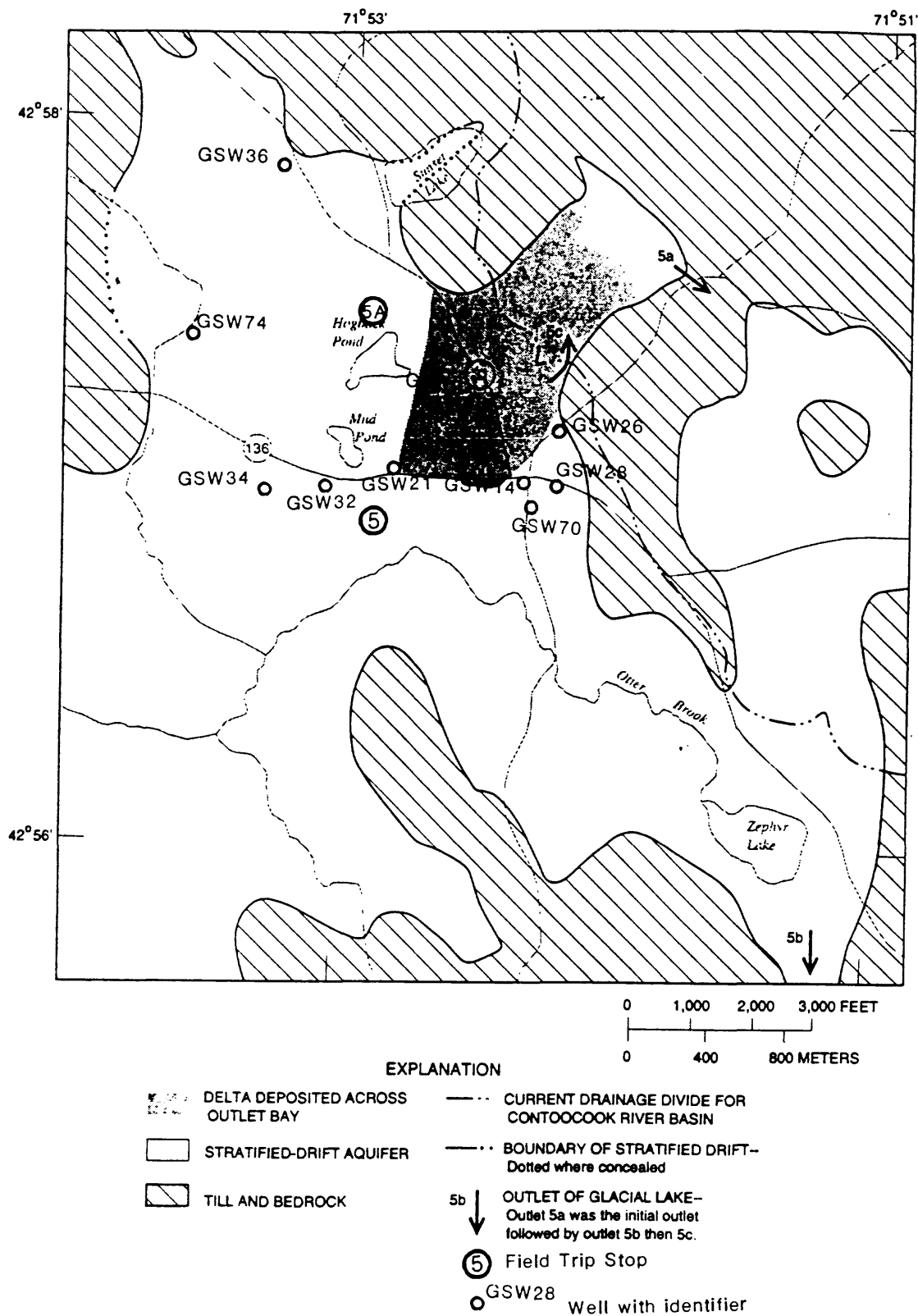
- 98.3 (0.2) **STOP 5.** Just before railroad crossing, park on right (south) on dirt shoulder. You need owner's permission to enter. On foot, follow the dirt road down to the right about 500 feet to the foot of a delta that was built into glacial Lake Contoocook at the 820-840-foot spillway elevation. A small pit has been dug into the side of this flat-topped lobate delta and has exposed foreset beds that parallel the topographic surface. The absence of faulting and the nearly perfect deltaic shape indicate that this landform was built into open water and that it was not in contact with glacial ice (at least on this side). Go to the top of the landform and look southward across the swampy meadows in order to imagine glacial Lake Contoocook occupying the lowlands here. Walk around the foot of the delta toward the southwest. Gully erosion has exposed foreset beds in several places. (See figure 7.)

**Return to vehicles and head east on Route 136 toward Greenfield Center.**

- 98.8 (0.5) Turn left (north) onto Route 31 north.
- 99.1 (0.3) Road crosses glacial Lake Contoocook outlet channel in glacial-outwash deposits at an elevation of 820-840 feet in downtown Greenfield. This outlet channel is expressed as a major swale in the fields to left (west) of road and as a shrub swamp to the right (east) of road. Meltwater flowed eastward down this channel to the headwaters of Rand Brook in the Piscataquog valley.
- 99.7 (0.6) **STOP 5A. (Alternative to Stop 5)** Intersection with Crotched Mountain Rehabilitation Center Road on right (north). **PARK OFF SIDE OF ROAD.** Pit belongs to Greenfield State Park; entrance is on left (south) side of highway. Walk down chained-off dirt road about 0.1 mile. This pit shows foreset sand beds of deltaic deposits of outlet south of Zephyr Lake, the outlet associated with the 840-860-foot spillway elevation of glacial Lake Contoocook. (See figure 7.)

**Return to vehicle and continue north on Route 31.**

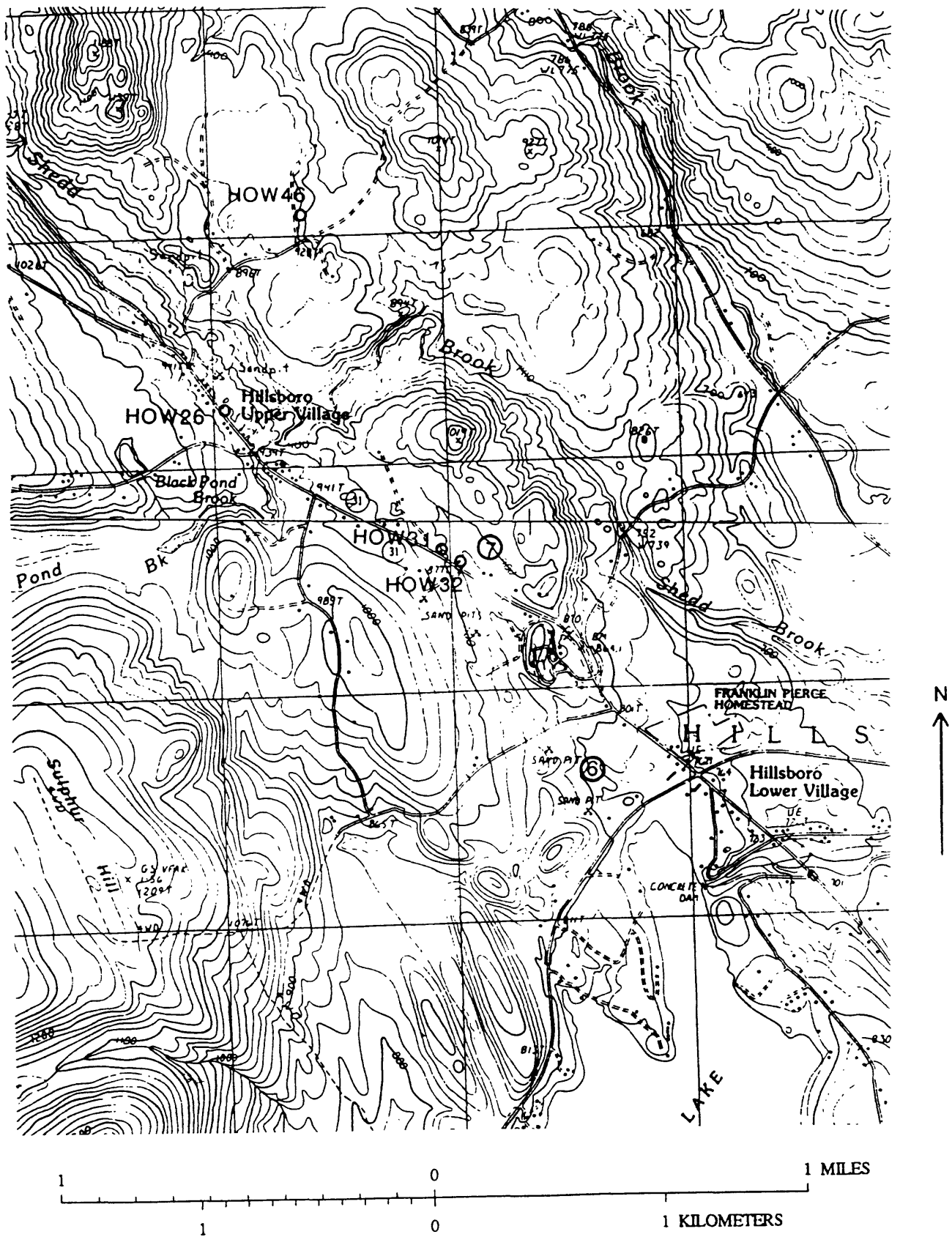
- 103.9 (4.2) Bear right (north) toward Route 47 around bend.
- 104.0 (0.1) Turn left (west) in downtown Bennington on Route 31. Go across Contoocook River and then southward.
- 106.3 (2.3) Intersection of Routes 31 and 202. Turn right (north) and go north on Routes 31 and 202.
- 110.7 (4.4) Downtown Antrim. Bear left (north) onto Route 31 (leave Route 202).
- 114.3 (3.6) Turn right (northeast) onto Routes 9 east and 31 north.



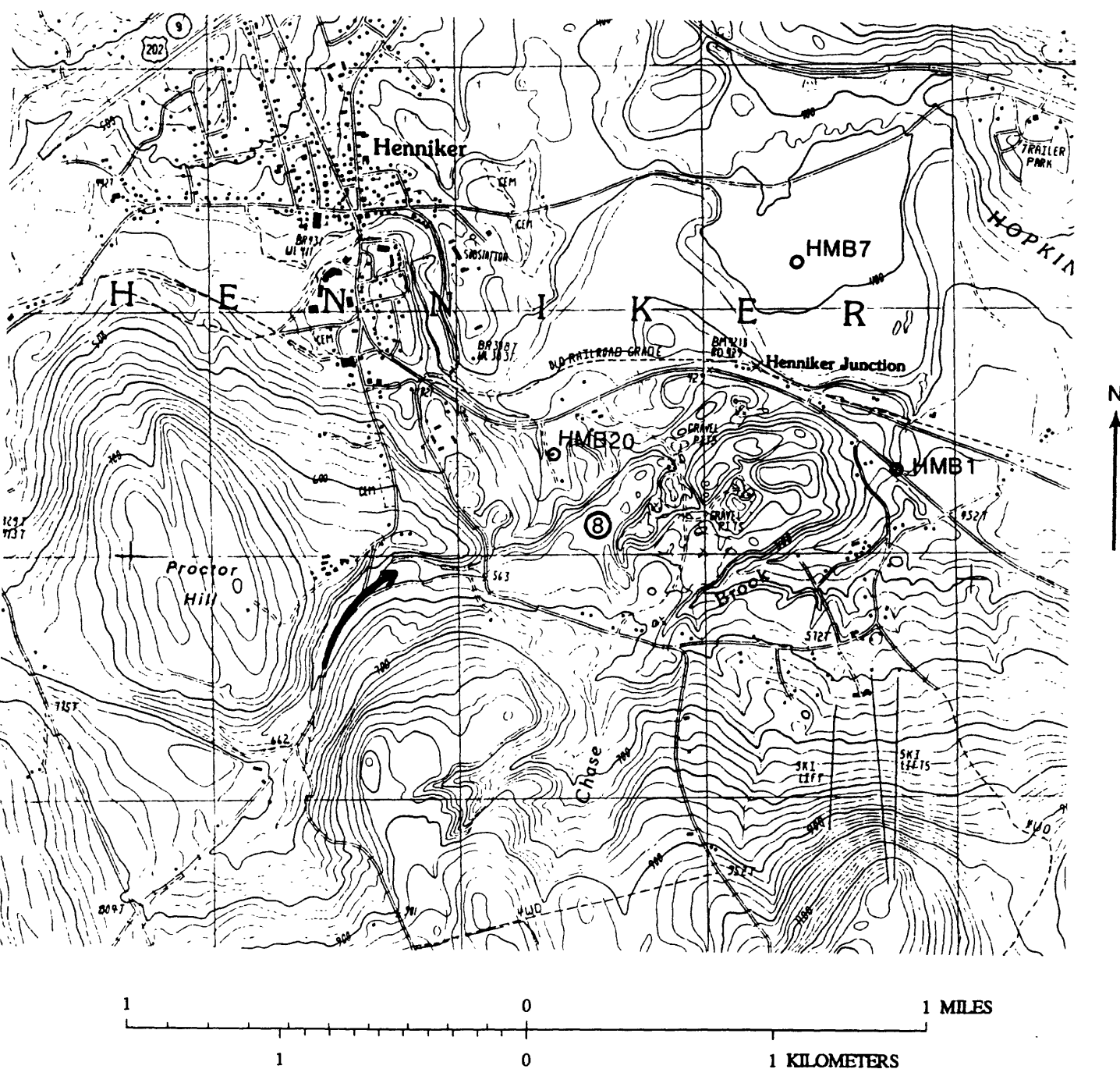
**Figure 7.** Stratified-drift aquifer map showing surficial and subsurface data and outlets for stage 5 (see appendix 2) of glacial Lake Contoocook, Greenfield, N.H. Stops 5 and 5A are located at the large circles, and drill-hole data are given in appendix 1. (Modified from Moore, 1995.) Base from U.S. Geological Survey, 1:24,000, Peterborough North, N.H., 1987, and Greenfield, N.H., 1987.



- 114.7 (0.4) **STOP 6.** Turn left (northwest) into the New Hampshire Department of Transportation pit (white garage and gas pumps). Go to back of pit (about 0.2 mi.). (See figure 8.) Exposure is an ice-contact ridge that arcs (is lobate) across the valley. The top elevation indicates that this feature is graded to the 820-840-foot spillway elevation of glacial Lake Contoocook. Apparently these materials were deposited within the stagnant ice zone. Some well-sorted gravel that is draped over the ice-contact deposits is interpreted to represent a beach where the sediments from the ice-contact deposits were reworked.
- 114.9 (0.2) Turn left (northeast) out of pit onto Routes 31 north and 9 east.
- 115.7 (0.8) Turn left (northwest) out of pit onto Route 31 north.
- 115.95(0.25) **STOP 7.** Turn right (northeast) to farmhouse and barn. Ask permission to visit pit up back, and then drive into pit. Pit contains bottomset, foreset, and topset beds of deltaic deposits that are graded to the glacial Lake Contoocook 820-840-foot spillway elevation, which is more than 12 miles south of here. Two more deltas of this glacial-lake stage are found northwest of here. This pit contains cut-and-fill structures and material that is predominantly medium to coarse-grained sand. (See figure 8.)
- 116.2 (0.25) Leave pit and turn left (southeast) onto Route 31 south.
- 116.95(0.75) At junction with Route 9 turn left (northeast) onto Route 9 east.
- 126.35(9.4) Turn right (south) onto Route 114 and go south toward Henniker.
- 127.65(1.3) In downtown Henniker, go straight across intersection.
- 128.4 (0.75) Turn right (south) onto gravel road just past Denny's Automotive Service and go into CON-AGG gravel pit.
- 129.15(0.75) **STOP 8.** Drive into main pit and go past crusher into rear of pit. The pit is a treasure house of glacial depositional features. Those we wish to emphasize for this trip are foreset beds, lake-bottom sediments, collapse along the ice-contact side to the north, and a large alluvial fan built out from an impressive erosional channel at the west end. This feature resulted from the catastrophic draining of the 820-840-foot spillway elevation outlet level of glacial Lake Contoocook. Material that was eroded from the outlet channel at this stop was redeposited here in a lower lake level. Richard B. Moore and Robert D. Jarrett (U.S. Geological Survey, Water Resources Division) are in the process of estimating the volume of this flow. (See figures 2 and 9.) Robert Jarrett has previously estimated the paleodischarge of the Bonneville flood in Idaho (Jarrett and Malde, 1987).



**Figure 8.** Topographic map showing location of Stops 6 and 7 in deposits of glacial Lake Contoocook, Hillsboro, N.H. Drill-hole data are given in appendix 1. Base from U.S. Geological Survey, Hillsboro, N.H., 1:24,000, 1987, and Hillsboro Upper Village, N.H., 1:24,000, 1987.



**Figure 9.** Topographic map of the Henniker area, New Hampshire, showing location of Stop 8. This stop is located in stratified deposits derived from the erosion of a channel in till, which is indicated by an arrow showing direction of transport. Drill-hole data are given in appendix 1. Base from U.S. Geological Survey, Henniker, N.H., 1:24,000, 1987.

- 129.9 (0.75) Leave pit and turn left (west) onto Route 114 north.
- 131.8 (1.9) Go east on Routes 9 and 202.
- 139.2 (7.4) Join Route 89 south going toward Concord.
- 141.7 (2.5) Pass the Clinton Street intersection and stay on Route 89.
- 143.3 (1.6) Take next exit (the Bow exit). Turn left (north) at end of ramp.
- 143.7 (0.4) Hampton Inn is on the right (east). **END OF DAY 1 TRIP!!!**

## **ROAD LOG**

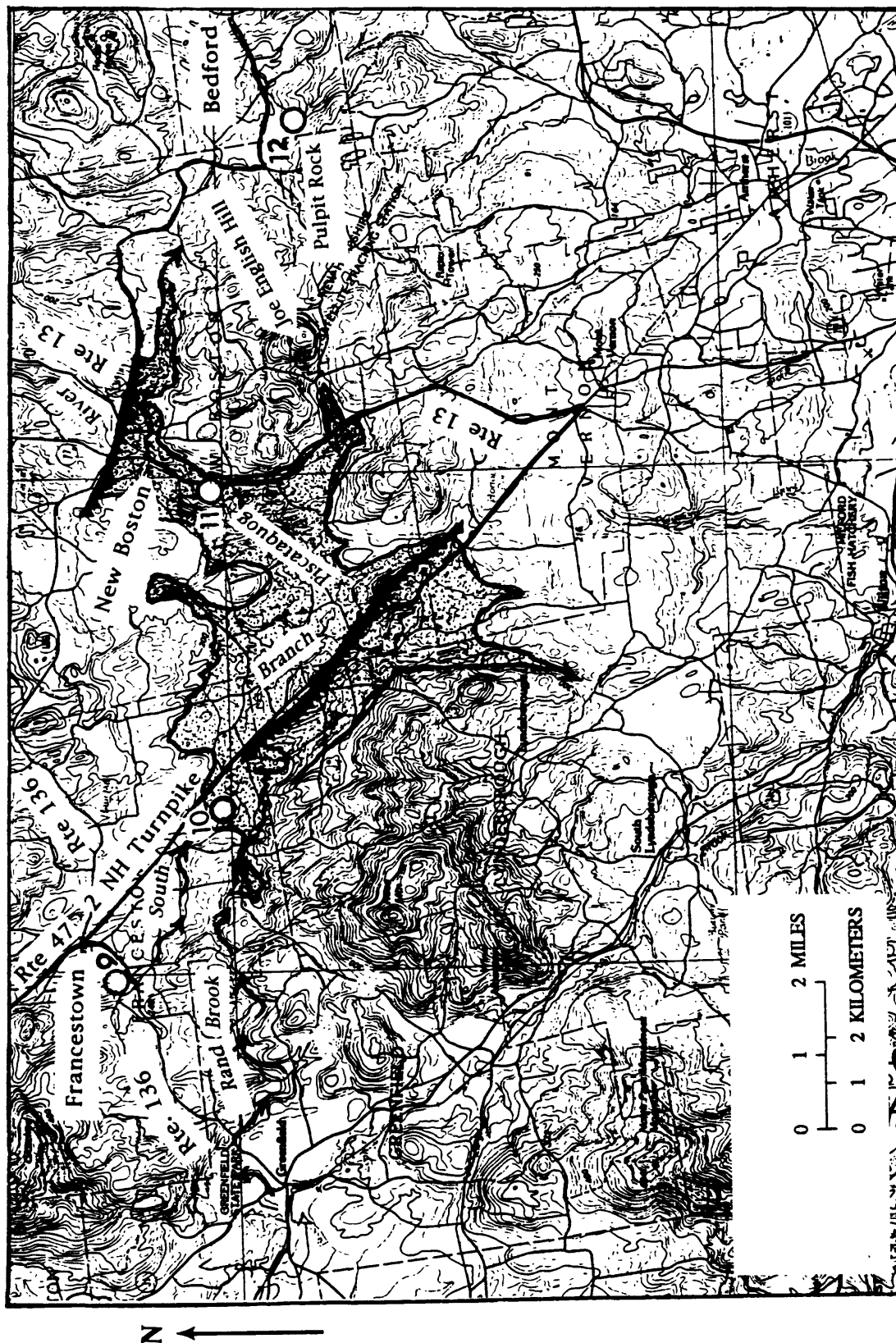
**Day 2, Sunday, May 23, 1993**

### **Piscataquog Drainage Basin**

The purpose of the second day's trip (fig. 10) is to examine glacial features in the Piscataquog drainage basin, where we will find evidence for glacial readvance, a delta built into glacial Lake Piscataquog, a complex ice-channel filling, and giant potholes at Pulpit Rock in Bedford, N.H. These potholes were carved by glacial meltwater that drained glacial Lake Piscataquog and periodic, catastrophic (jokulhlaup) floods that resulted from rapid melting of the glacier and (or) sudden breaching of the residual ice dam. (A similar gorge that contains a large but not so spectacular potholes is in Walker Brook just over 2 miles south of the 920-930-foot spillway elevation for glacial Lake Souhegan in the Ashby quadrangle (off Route 31). That particular part of Walker Brook was the major drainage for at least two stages of glacial Lake Souhegan. (See figure 1 for location of Walker Brook potholes.)

#### **Cumulative mileage point to point \_\_\_\_\_**

- |      |       |  |
|------|-------|--|
| 0.0  | (0.0) | Assemble at Hampton Inn, Concord, N.H. parking lot. Turn left (south) as you exit onto street.   |
| 0.1  | (0.1) | Turn right (west) onto Interstate 89 north.  |
| 6.7  | (6.6) | Entering the Contoocook Drainage Basin.  |
| 7.2  | (0.5) | Low point in road. A small, unnamed glacial lake was trapped here between the ice and the watershed divide to the south (left of road). The village center of the town of Hopkinton was built on top of a delta that was associated with this glacial lake. North of the delta is a feeder esker that is used as a municipal water source for the town of Hopkinton. |
| 8.1  | (0.9) | Bear left on Route 9 west (exit 5) toward Hillsboro.   |
| 12.1 | (4.0) | Cross Contoocook River.  |
| 14.5 | (2.4) | Pats Peak Ski Area is visible across small field on left (south). At the lower right of Pats Peak is a pit in the delta that we visited at the last stop on Day 1. Deltaic foreset beds are visible, even from this distance.  |
| 162  | (1.7) | Route 114 overpass.  |

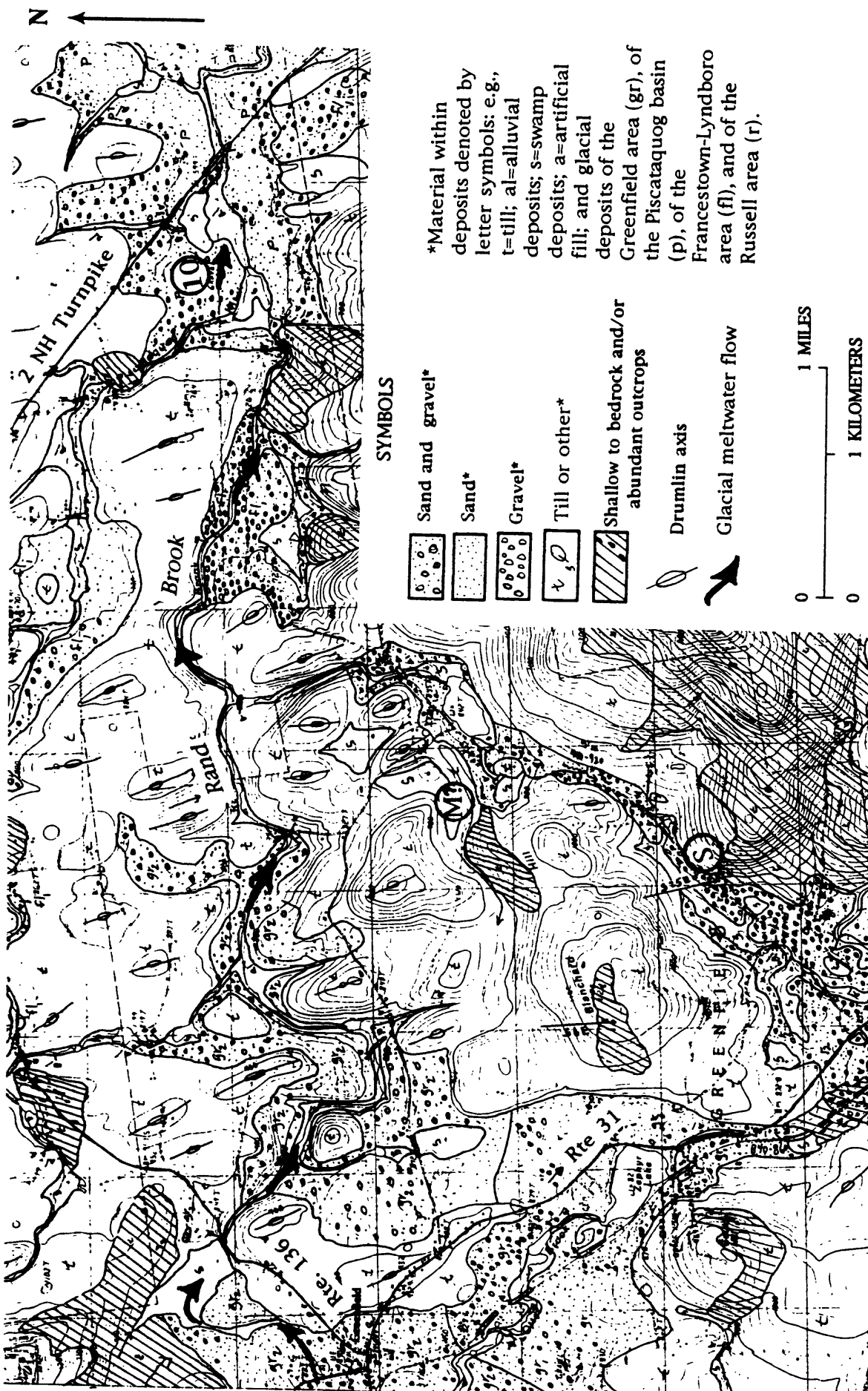


**Figure 10.** Topographic map showing the locations of Stops 9 through 12 (Day 2). Also shown are generalized shorelines of glacial Lake Piscataquog, major ice-frontal positions (thick, toothed lines), outlets, and outlet channels in part of the Piscataquog drainage basin near Francestown, New Boston, and Bedford, N.H. (Arrows) Base from U.S. Geological Survey, Lowell, N.H., 1:100,000, 1988.

- 21.5 (5.3) Exposure on right (north) of diamicton (?), till (?), or ice-marginal position (?). Roughly bedded.
- 22.7 (1.2) Downtown Hillsboro.
- 24.1 (1.4) Turn left (south) onto Route 202 and go toward Antrim. The Contoocook River parallels Routes 202 on the left (east). (Pass through Antrim at about mile 30.)
- 31.9 (7.8) Monadnock Paper Mills on left.
- 32.9 (0.3) At stop sign in downtown Bennington, continue straight across the intersection on Route 47 and go toward Frankestown.
- 35.8 (2.9) Crotched Mountain Ski Area is on right (south). This is the approximate location of the drainage divide between the Contoocook and Piscataquog drainage basins.
- 32.6 (0.7) At junction of Routes 31 and 47, turn left (east) onto Route 47.
- 40.2 (4.4) At stop sign in downtown Frankestown, turn right (south) onto Route 136 west and go toward Greenfield.
- 41.1 (0.9) Turn right (northwest) onto Muzzey Road.
- 41.2 (0.1) **STOP 9.** Turn right (east) into Muzzey Road pit, a readvance site. Thrust faults, excessively compact stratified drift, till (?), and (or) very coarse grained colluvium are on top. There also appears to be an ice wedge or crevasse filling (?). At different times, all or some of these features have been exposed in this pit, along with many other phenomena. Perhaps this represents a minor readvance of ice that may be correlated with a site discovered in the Merrimack valley near Manchester (Stone and Koteff, 1979) and several other features in the area (figs. 10 and 11). The stratified materials here were deposited originally in contact with or beyond adjacent ice and ultimately were graded to a spectacular 670-680-foot elevation gorge in Lyndeborough. That gorge is just east of the Greenfield quadrangle border (in the New Boston quadrangle) about 4 miles south of the point where Cold Brook leaves the quadrangle (southernmost outlet, just east of the word Lyndeborough in figure 10).

**Leave pit and return to Route 136.**

- 41.5 (0.3) Turn left (east) onto Route 136 and go back toward the center of Frankestown.
- 42.5 (1.0) Frankestown center. Take a sharp right (southeast) onto 2 NH Turnpike S (road sign).
- 44.1 (1.6) Cross South Branch Piscataquog River.



**Figure 11.** Surficial geologic map showing the valley of Rand Brook from Greenfield to the Francetown delta (Stop 10 at triangle), which was built into glacial Lake Piscataquog. M? is a ridge that appears to be cored by till and could be a moraine. It is elongate transverse to the general directions of drumlins in the area. S is the location of a previously exposed saprolite. Base from U.S. Geological Survey, 1:24,000, Greenfield, N.H., 1987.



- 44.9 (0.8) Turn right (southwest) onto gravel road (after passing Abbotville Farm field). Drive into pit, about 0.3 mile. Be sure and ask for permission to enter.

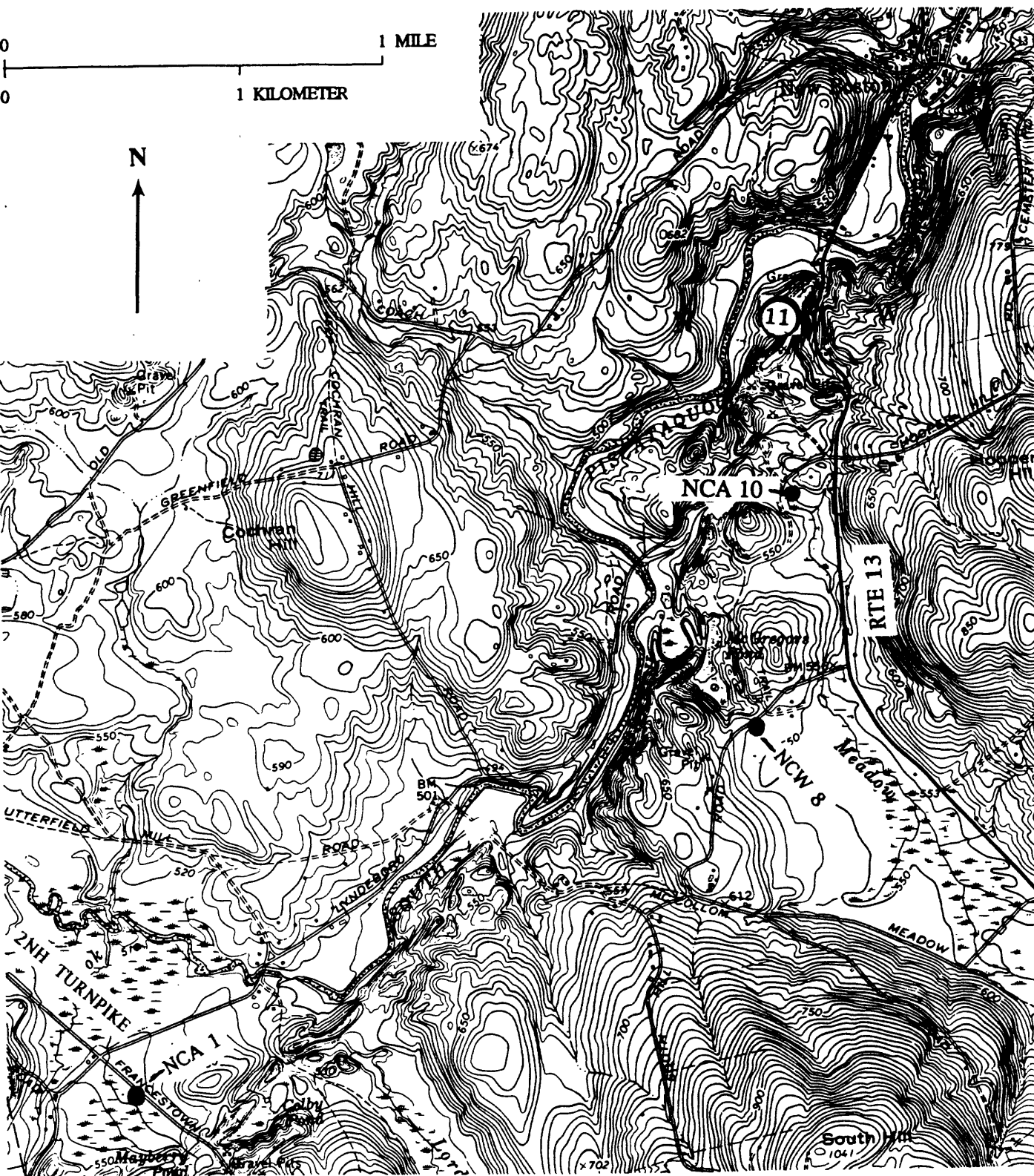
**STOP 10.** This pit is cut into a complex delta that was built into glacial Lake Piscataquog at an elevation of approximately 600 feet. Most of the delta was deposited in open water and was not in contact with adjacent ice. (Exposed foreset beds on the outer edge of the delta parallel the topography and have little or no faulting; one exception is an exposed crevasse that seems to have opened up on the perimeter (foreset beds) of the delta and subsequently was filled with coarse-grained topset materials.) Most of the exposed stratified material in the pit appears to have been contributed from glacial meltwater that flowed southeast down the valley of the South Branch of the Piscataquog River. However, we think that another major contributor to this delta was glacial meltwater that drained glacial Lake Contocook at the Greenfield outlet to the west. The water flowed down Rand Brook where it carved a deep valley. Rand Brook also contains abundant coarse-grained-terrace deposits of the same age (for example, well-sorted pebble-cobble gravel in exposures along Russell Station Road). Look for evidence for these two provenances in the pit. Convolutional bedding and other interesting sedimentation features may be found here (fig. 11).

- 45.7 (0.8) Leave road to gravel pit and turn right (southeast) onto 2 NH Turnpike S headed south.
- 46.2 (0.5) Cross South Branch Piscataquog River.
- 48.4 (2.2) Pass Lyndeborough Road, but continue straight. [Lyndeborough Road is a possible shortcut for light cars to the next stop (road and stop 11 shown on figure 12)].
- 48.8 (0.4) Abandoned pit on left (northeast) in sand and silt deposits of glacial Lake Piscataquog.
- 52.7 (3.9) Turn left (north) onto Route 13 north.
- 57.6 (4.9) Pass Lyndeborough Road on left (west), but go straight ahead on Route 13.
- 58.1 (0.5) Pit entrance on left (west).

**STOP 11.** Enter gravel pit on left. **Please stay away from edges of pit here; they are vertical in places!!!** The pit exposes a segment of an extensive landform that may be partly an esker, partly a subglacial lacustrine fan deposit, and partly an open-air ice-channel filling (fig. 12). This long, sinuous ridge appears to have been graded to a notch northeast of Joe English Hill at an elevation of 580-590-foot (Koteff, 1970). Coarse-grained gravels in the deepest part of this pit may be an esker segment. Coarse-grained till(?) on the northwest side (faintly bedded in part) may represent active ice there or flowtill. Parts of the northwest side have fine-grained sand beds draped over the sides of the coarse-grained core material, which indicates that the lake persisted after the ice front receded from direct contact with the core deposits. A transverse section through part of this pit contains fine-grained sand stratigraphically over a core of sand with cut-and-fill structure. Also, a thick set of coarse-grained topset beds is interbedded with finer-grained foreset (?) beds off either side of the landform. Look for evidence of flow directions, ice-contact slump faults, ice shove, and the like.

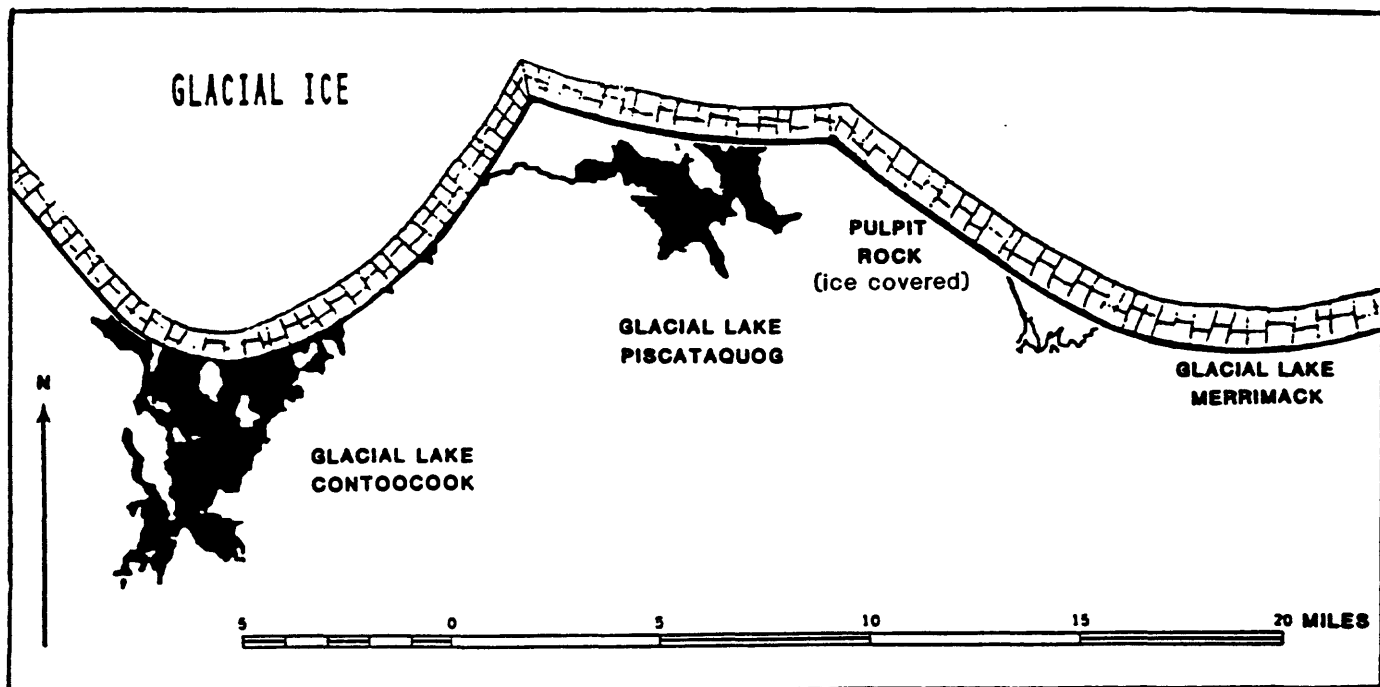
We may be able to drive into the pit. The mileage assumes that we park at the entrance and walk in.

- 58.1 (0.0) Turn left (north) onto Route 13.
- 58.8 (0.7) Turn right (east), continue on Route 13 north, and cross the South Branch of the Piscataquog River.
- 58.9 (0.1) Go straight ahead on Central Street at intersection (Route 13 goes left toward Goffstown here).
- 59.2 (0.3) Turn left (east) onto Bedford Road.
- 63.2 (4.0) At stop sign, turn right (south) and continue on Bedford Road.
- 64.4 (1.2) At stop sign, turn left (east) onto New Boston Road.
- 64.7 (0.3) **STOP 12A.** Spectacular exposure of waterworn bedrock in abandoned pit on left (north) side of road. Just at the edge of the pit by the road is a bedrock surface that escaped being completely worn by water and has retained some glacial striations.

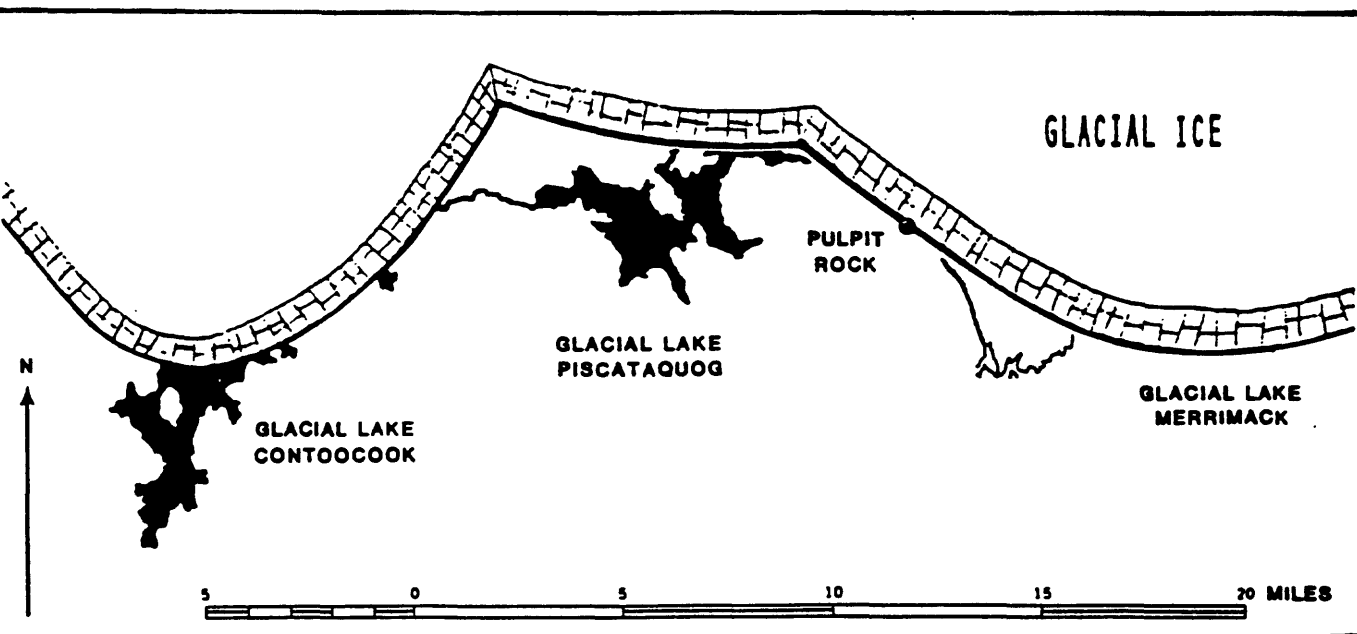


**Figure 12.** Topographic map showing the location of Stop 11, which consists of ice-channel fillings that are graded to the 580-590-foot-elevation outlet stage of glacial Lake Piscataquog. Logs for drill holes are given in appendix 1. Base from U.S. Geological Survey, New Boston, N.H., 1:24,000, 1968.

- 64.9 (0.2) **STOP 12B.** Pulpit Rock Conservation Area in Bedford. Pulpit Rock is the largest of a series of huge potholes along a 0.5 mile stretch of Pulpit Brook, which today has a drainage area above Pulpit Rock of less than one square mile. The pothole called Pulpit Rock is partly buried by sediments; however, the exposed part measures 42 feet deep and about 23 feet wide! Each of the potholes along Pulpit Brook is just below a strike ridge. The following are the conclusions of the junior author regarding the formation of these huge potholes: (1) They probably formed at the base of a falls or cascade at or near the ice margin. The ice margin is necessary to provide a drop in elevation (hydraulic head) not present in the land surface upstream of Pulpit Rock. (2) They may have formed successively at different times and at different ice-marginal positions. (3) The ice margin must have remained in this area for a considerable period of time in order for these potholes to form. (4) A plentiful source of water probably resulted from an ice-marginal configuration that captured the drainage from the two basins to the west, the South Branch of the Piscataquog and the Contoocook, and directed it down Pulpit Brook. (5) Perhaps periodic jokulhlaup floods contributed to the development of potholes (this could have resulted from a series of minor advances and retreats of the ice margin in the two western basins (figs. 13 and 14).



**Figure 13.** Schematic diagram showing a possible ice-marginal position and the development of glacial Lake Contoocook and glacial Lake Piscataquog prior to draining through the Pulpit Rock area of Bedford, N.H.



**Figure 14.** Schematic diagram showing a possible ice-marginal position just after the release of glacial-ice-dam-break floods down through the Pulpit Rock area of Bedford, N.H.

**Leave parking lot. Turn right (east) onto New Boston Road.**

- 68.6 (3.7) At blinking light at intersection, turn left (north) onto Wallace Road.
- 72.1 (3.5) Turn left (northwest) at stop sign onto Route 114 in Goffstown.
- 72.8 (0.7) Continue north on Routes 114 and 13 through the intersection with Route 13.
- 72.9 (0.1) Cross the Piscataquog River.
- 73.1 (0.2) Bear right (north) and follow Route 13 north, leaving Route 114 and the Goffstown village center.
- 82.6 (9.5) Turn right (north) at stop sign in the north part of Dunbarton and continue north on Route 13.
- 86.7 (4.1) Turn right (east) onto entrance ramp for Interstate 89 south.
- 88.3 (1.6) Take next exit (the Bow exit). Turn left (north) at end of ramp.
- 88.7 (0.4) Hampton Inn is on the right (east). **END OF TRIP!!!**

**\* \* \* \* \***

## BACKGROUND INFORMATION AND PREVIOUS WORK IN THE AREA

Warren Upham (1878, p. 114-120) was among the earliest mappers of surficial geology in this area. His account of the glacial meltwater deposits in the Contoocook valley is comprehensive and is reprinted here for background and historical perspective.

### *Review and Conclusions.*

The continuousness in height of the plains of the Merrimack valley in Concord with those through which the last ten miles of the Contoocook flows, has been already noticed (p. 80). A comparison of this with the deficient height of the terraces of the Merrimack opposite to and for a few miles above the mouth of this river (pp. 78 and 79), leads to the conclusion that a large proportion of the modified drift of Concord was brought into the Merrimack valley by the Soucook and Contoocook rivers. The latter contributed to the plain of East Concord, and alone filled the large area between West Concord and Fisherville.

The extensive plains of the Contoocook, in the north-west part of Concord and through Hopkinton, occupy two basins of unequal size, which we must suppose held lakes at the first retreat of the ice-sheet. These were filled, as the melting of the ice continued, by the alluvium of its floods. A large share was supplied by the tributaries from the north; and the kames near West Hopkinton were formed by a glacial river, which descended at the head of the valley. To this point the formation of modified drift seems to have proceeded quite in the ordinary way.

In the east part of Henniker the first outlet from this valley was probably to the south-east into the basin of Piscataquog river. The moraine and kame which extend along the old line of the New Hampshire Central Railroad, at the south-west side of the alluvial area of the Contoocook, indicate a considerable period in which the terminal front of the rock-bearing glacier remained nearly stationary, succeeded by a period of retreat northward, when a large river, laden with sand and gravel, descended from the melting ice-fields. At the time of formation of this kame a small lake, nearly as deep as to cover its top, lay between the front of the glacier and the outlet of its waters to the south. The glacial river, entering this deep and quiet lakelet, deposited more quickly than usual nearly its whole freight, both of gravel and sand. Somewhat later, but while the outlet was still to the south, the kames on the north side of the valley south-west from Whittaker pond were formed; and we may presume that this date was nearly the same with that of the kames of West Hopkinton, which show that the valley of the Contoocook below was clear from ice. Not long after this time the glacial barrier between these basins disappeared, and drainage took its present course. Whether

the kames at the east side of Henniker village were formed before or after this change, cannot perhaps be determined. Their position, transverse to the Contoocook, shows that they were formed by streams from the melting glacier on the north in the valleys of Amy and Warner brooks, while the rapid retreat of the ice to the west and south-west appears to have been delayed by the high hills which closely border the river. It is not improbable that, when these waters first flowed towards the north-east down the Contoocook valley, a barrier of till near West Hopkinton, afterwards eroded by the river, held back a shallow lake which extended to the kames last mentioned. The deposition of the low alluvium of this area was going slowly forward during all the time occupied by this history.

The melting of the vast ice-sheet over New England proceeded from the coast to the north-west and north, so that lakes were temporarily formed in valleys which drain northward. The avenues by which the waters escaped from the upper portion of the Contoocook basin, or that part above Long fall in the west part of Henniker, appear to have been three in number, as follows: Southward, over the water-shed at the head of the valley in Rindge; towards the south-east, through Greenfield; and northward, along the course of the river. The length of this area is nearly thirty miles; and the outlet in Greenfield is about equally distant from its south and north ends.

The conspicuous kames, which extend five miles along the Vermont & Massachusetts Railroad between South Ashburnham Junction and Westminster, show that a large area of the ice-fields on the north-west poured their waters along this course. These kames are less than 200 feet below the plateau in Rindge, twelve miles distant, which forms the water-shed at the head of the Contoocook valley. Although the present drainage of the south part of Rindge and of Winchendon is into Miller's river and the Connecticut, there is no considerable depression; and the separation between this basin and the head of the Nashua valley, in which these kames are found, is not so high as the water-shed in Rindge. This area has not been explored; but the deposits of modified drift in Rindge make it probable that the melting of the ice-sheet, while its outlet continued in this direction, proceeded beyond this divide, including a portion of the Contoocook basin.



The principal outlet from the part of this basin in Hillsborough county appears to have been through Greenfield south-easterly to Souhegan river. South from this pass the east border of the Contoocook valley is formed by Pack Monadnock, Temple, Kidder, and Barrett mountains, which extend in a continuous range through the west portions of Temple and New Ipswich. Northward this valley has a high eastern water-shed two to four miles from the river, with no deep depression till we reach the pass through which we have supposed a former outflow towards Piscataquog river. The culminating points of this water-shed are at its south and north ends, in Crotched mountain and Craney hill.

When the melting of the ice-sheet had advanced so far as to open an avenue from this valley through Greenfield, we may suppose that large streams descended from the glacier to this point, by which the kames on the east side of the railroad south of the village, those between Hogback and Pollard ponds and along the road northward between Greenfield and Bennington, and those at Bennington station and for a mile north-west on both sides of Contoocook river, were in succession deposited. The fine alluvium of these streams was at first spread out in the level plain east of Cragin pond, while ice still remained over the area now occupied by this pond. A small lake was afterward formed by the melting of the ice on the north-west side of the pass. This lake received the finer drift brought down by the glacial rivers, producing the alluvial plain west and north-west from Greenfield.

A channel appears next to have been formed farther to the north-west, skirting the hills upon the east side of the valley and walled on the west by ice. This became filled by the nearly level-topped and terrace-like gravel and sand seen on the east side of the Manchester & Keene Railroad south from Bennington station, which seem to belong to the same date with the kames at this station and about Whittemore pond. The kames were probably formed in ice-channels which were narrow and somewhat higher than the former, with so rapid a descent that only coarse gravel was deposited in them by the summer floods, the sand being carried onward to the quiet waters of the channel below, which was an arm of the lake. With the full melting of the ice, however, such of the kames as had been formed over the middle of the valley sank to its bottom, and are found at a lower level than the principal deposits of fine

gravel and sand, which remain nearly at their original height upon the hillside.

The kames which we find south-west from Bennington, and a large portion of those north of Whittemore pond, are principally composed of sand and fine gravel. They were probably deposited at the mouth of the glacial streams where these entered the lake, nearly all the modified drift which was brought from the melting ice being thus accumulated in mounds, ridges, and terrace-like banks. The want of continuity in these deposits appears to be due to the irregular rate of melting and to the varying slopes assumed by the terminal front of the ice-sheet, the latter being determined by this rate and by the contour of the valley.

The lack of stratified drift in the valley west from the Greenfield plain seems to show that the ice over this area, while it still confined the little lake on the east, had been melted nearly to this level, sending its alluvium to form this plain; and that the remainder disappeared from the valley without sufficient currents to form alluvial deposits. All the material which it still held was dropped as unstratified till, unless we except rare instances of kames like the isolated banks of sand seen on the hillside east of the river near the north line of Peterborough.

The first deposit belonging to this period that we meet in going up the valley is the high level-topped sand north-west from North Peterborough. This and other terrace-like deposits extending to Peterborough appear to be of similar origin with those already noticed south of Bennington station. Kames of the common type, composed of coarse gravel and sand, occur one and two miles farther up the valley; and they are increased in amount as we approach the line between Peterborough and Jaffrey, appearing to have come principally from Sharon on the south-east. We may suppose that these, as in Bennington, were deposited at the same date with the sand which partly filled the opening channel below. This was a branch of the lake, and the sand fell in irregular and thin deposits with stratification conforming to the sloping sides of the valley. The occasional boulders which we find embedded in the alluvial deposits of this lake appear to have been dropped by floating masses of ice broken from the glacier which bordered its shores.

Going down the valley we find evidence that the glacial melting advanced beyond Hillsborough Bridge, while its outlet continued to be

through Greenfield. The last blockade of the ice-sheet in its retreat to the north may have been at Long fall, in the west part of Henniker, where the high hills leave a narrower space than usual for the passage of the river. The large proportion of sand in the kames of the north part of Bennington is what we should expect, if their deposition was at the mouth of glacial rivers where they entered the lake. The most important testimony, however, is given by high deposits of sand and fine gravel, like that on Hedgehog hill in Deering. The widened lake now filled the whole valley; and these deltas, brought in by glacial rivers or tributary streams, mark its height and shore line, and enable us to gauge the floods which were supplied from the melting ice.

The earliest of these lake-shore deposits are the plain of Greenfield and that of Hancock village. Both of these have the same height with the outlet, over which there as yet flowed only a shallow stream. When the lake had advanced north to Clinton village in Antrim, the depth of its outflow was probably 20 feet, as shown by a level-topped ridge of sand and fine gravel exposed on the north side of Great brook and the road, a quarter of a mile east from Hastings's mill. This deposit extends a quarter of a mile to the north, and also occurs south of this stream, by which it was formed about at the level of the lake. High sand was also found three miles farther north, on the water-shed between Cochran brook and North Branch, at the south-west side of Riley mountain. This is two and a half miles due west from that on Hedgehog hill. Both these deposits are level-topped deltas of glacial streams that descended to the lake from the north, having the place of their inlet determined by the gap of the adjacent hills. Their heights are the same, and show that at the time of their formation 50 feet of water poured over the outlet in Greenfield. Somewhat later, when the lake reached its greatest extent and received its largest tribute from the more rapidly melting ice-sheet, the depth of water discharged was 80 feet, as shown by a delta-terrace half a mile south-west from Hillsborough Centre, and by plains which occur at the same height north-east of Hillsborough Upper Village. All these deposits are level-topped, or nearly so; and their position is generally on steep hillsides, with no barrier, if the drainage had been the same as now, to prevent their being carried forward to the bottom of the valley. Other deltas similar to these might probably be found by a more thorough exploration of the ancient lake shore.

*Heights of the Outlet and Deltas of the Lake which filled the Contoocook Valley through Hillsborough County in the Champlain Period.\**

Outlet of lake, $1\frac{1}{2}$ miles south-east from Greenfield, being the lowest point of water-shed between Contoocook and Souhegan rivers (2 feet lower than the railroad summit), 863.	Delta at Hancock village, 862.
Cragin pond, 830.	Delta at Clinton village, Antrim, 883.
Greenfield station, 834.	Delta south-west of Riley mt., Antrim, 912-915.
Pollard pond, 810.	Delta on Hedgehog hill, Deering, 905-920.
Delta cut by the railroad $\frac{1}{2}$ mile north-west from Greenfield station, nearly the same in height with the fair-ground, 864.	Delta $\frac{1}{2}$ mile south-west from Hillsborough Centre, 940.
	Delta north-east of Hillsborough Upper Village, 942.
	Kames at church and cemetery between Hillsborough Upper and Lower Villages, 930.

The depth of this lake was from 200 to 350 feet, as will be seen from the following:

*Heights along Contoocook River.*

Head of Long fall, near county line, 546.	Foot and head of fall at North Peterborough, 714-724.
At Hillsborough Bridge, foot of falls, 564; lower dam, 576; upper dam, 591.	Same at Peterborough, 727-734.
At Bennington, foot of falls, 606; Paper-mill pond, 635; Kimball's dam, 645; King's dam, 655; Whitney's dam, 668; Powder-mill dam, 676.	River at county line, about 875.

At length the melting of the ice along the lower part of the valley at the north-east met the already open portion which extended through Hillsborough county, and the drainage of the basin took its present

\* The heights from Greenfield to Paper Mill Village inclusive, given in Vol. I, p. 268, are too low, requiring the addition of 36 feet to agree with recent surveys of R. S. Howe for the Hillsborough & Peterborough Railroad, and with those of Hon. J. A. Weston for the Manchester & Keene and Monadnock railroads, published in Vol. I, p. 271. The heights given above are derived from the profiles of these railroads, or from special survey. They are stated in feet above the sea.

Our levelling to determine the height of deltas gave opportunity to note also the water-power of two tributaries of the Contoocook.

*Heights along Great Brook, Antrim.* Mouth of brook, 600; Thompson's mill-pond, 624; Goodell's saw-mill pond, 641; Goodell's next pond, 657; Poor's saw-mill pond, 672; Goodell's cutlery-shop pond, 703; Kelsey & Co.'s pond, 717; Baptist and Methodist churches, South Antrim, 719; road at foot of sand delta, Clinton village, 853; hay-scales platform at Clinton village, E. Z. Hastings's house, and his mill-pond, each, 914; Gregg's pond, according to an old survey, 1064.

*Heights along North Branch in Hillsborough and Antrim.* Mouth of Branch, 592; mouth of Beard's brook, near foundry, 600; Foundry mill-pond, 618; Young's (formerly Dickey's) mill-pond, 702; Tannery mill-pond, 728; still water,  $\frac{1}{4}$  mile above Hillsborough Lower Village, 750. (The following heights of this stream in Antrim are from survey by G. C. Patten, in 1874.) Foot of rapids,  $\frac{1}{2}$  mile east of W. Curtis's, 755; Curtis's dam, 852; foot of falls at North Branch village, 862; Parkhurst's dam, 902; at Boutwell's bridge, 1 mile above this village, 985; proposed reservoir of 100 acres above do., 1025; J. Loveren's dam, 1077; foot of falls below do., 1024.

course to the north. The erosion of the high deposits in the south part of Peterborough and the tribute of streams near the source of the river now supplied the low alluvium which extends for two miles below North Peterborough. The kames in Bennington probably also suffered considerable erosion, which, with the important streams on the west, furnished the similar low alluvial deposits of Antrim, Deering, and Hillsborough.

More than one-half century later, Goldthwait and others (1951, p. 37, 41 and 42) published their ideas on deglaciation style in the area.

### Glacial Drainage Courses

In the Contoocook Valley scattered deposits with flat tops and delta structure, but without delta form, were long supposed to mark "Glacial Lake Contoocook."<sup>1</sup> It now seems clear that no deep lake occupied this valley but a lingering ice mass rested against its sides catching meltwater and sand in pockets high above the valley floor. So, the southward descent of the kame levels from Hillsborough to Bennington indicates the original southward discharge of a marginal drainage system. There is no outlet at the south end of this Contoocook area, but only the usual eskers and outwash plains. At the northeast corner of the Contoocook Valley in Hopkinton, where a "retreating ice front" would have opened a later outlet, are kames, eskers and outwash plains but no river channels. The ice, wasting down into the Contoocook Valley, doubtless had a southward slanting

<sup>1</sup> Upham, W. Modified Drift Along the Contoocook River. In his chapter, Modified Drift in New Hampshire, p. 103-120, vol. 3, part 3, Geology of New Hampshire by C. H. Hitchcock. 1878.

surface which receded northward as it melted, but it seems to have thinned downward more than backward without forming a wide sheet of open water at any time.<sup>1</sup>

In many other valleys the same southward or eastward flow of meltwaters is evident: Upper Connecticut, Baker, Smith, Warner, Piscataqua, Lamprey, and Souhegan Rivers. Each one has kames or terraces in descending levels seaward. Perhaps some of the esker chains described earlier in the northern and western parts of the State (upper Ammonoosuc Valley, Connecticut Valley south from Lyme, Madison, Pine River) were being built at the same time as great sand plains were being spread in the southeastern lowlands. In valleys which today flow northwestward (Israel River, Upper Ammonoosuc River, Upper Mascoma River) there is evidence in the stones of an esker, or the slope of a channel, or in the decline of kame terraces that glacial waters flowed opposite to those today.

Where the water flowed through chains of pools, between an ice tongue and the valley sides, meltwater built many kame terraces with typical *delta structure* (Figure 19), but never the delta form. These



Figure 19. Structure of the layers of sand in a delta at Lancaster. Water coming from the right swept sand onto the inclined "foreset" beds, building them out into a former lake on the left. It covered the top with horizontal "topset" gravel beds just about at the surface of the glacial lake. (Photo by J. W. Goldthwait.)

pools were always filled up completely so that the bedded gravels and sands rested against the ice on one side and sloping ground on the other.

Long mistaken for deltas or remnants of deltas,<sup>1</sup> these flat-topped stratified deposits are still thought by some to register levels of extinct glacial lakes, but it is now generally agreed that most of them formed when the valleys were occupied by thin honeycombed ice rather than open water. According to this view, broad "Glacial Lakes Winnepesaukee and Contoocook" never existed. However, the Merrimack Valley below Franklin contains a widespread series of bedded lake-bottom sediments so it is an exception, and similar silts and clays reach all the way up the Connecticut River Valley from Hartford, Connecticut to Littleton, New Hampshire, justifying the names glacial "Lake Hitchcock" and "Lake Upham."

Some of the meltwater flowing on ragged, honeycombed ice found passageways within and at the base of the last rotten ice, because sorted gravels and sands pouring through tunnels and canyons settled to the bottom of the slack parts of each water course. Now that

<sup>1</sup> Goldthwait, J. W. *The Geology of New Hampshire*. N. H. Acad. Sci. Handbook No. 1, p. 42. 1925.

An article by Richard Bridge Moore (1995) gives substantial background information on the surficial geology in the Contoocook basin area (appendix 2).

Carol T. Hildreth has mapped the surficial geology of three 7 1/2-minute quadrangles (Greenfield, Greenville, and Peterborough South) and parts of three others (Peterborough North and the New Hampshire parts of Ashby and Ashburnham) in the southern part of the study area.

Throughout the field trip, we will demonstrate evidence that supports the existence of glacial lakes in the Contoocook, Souhegan, and Piscataquog basins. How much open water existed at any given stage is debatable.

## **GLACIAL LAKE SHORELINES AND OUTLET ELEVATIONS**

Because of isostatic rebound that took place after the continental glacier receded from this area, glacial lake-level surfaces in the New England area slope downward to the south-southeast about 4.7-4.9 feet per mile, as shown in figure 15 (from Koteff and others, 1987). The various stages of glacial Lake Contoocook that were determined by projecting the outlet elevations northward at that slope (Moore, 1995) are shown in figure 16.

The following is a list of outlet elevations (in feet) for some of the different stages of the other two glacial lakes described on this trip:

### **SOUHEGAN**

(feet)

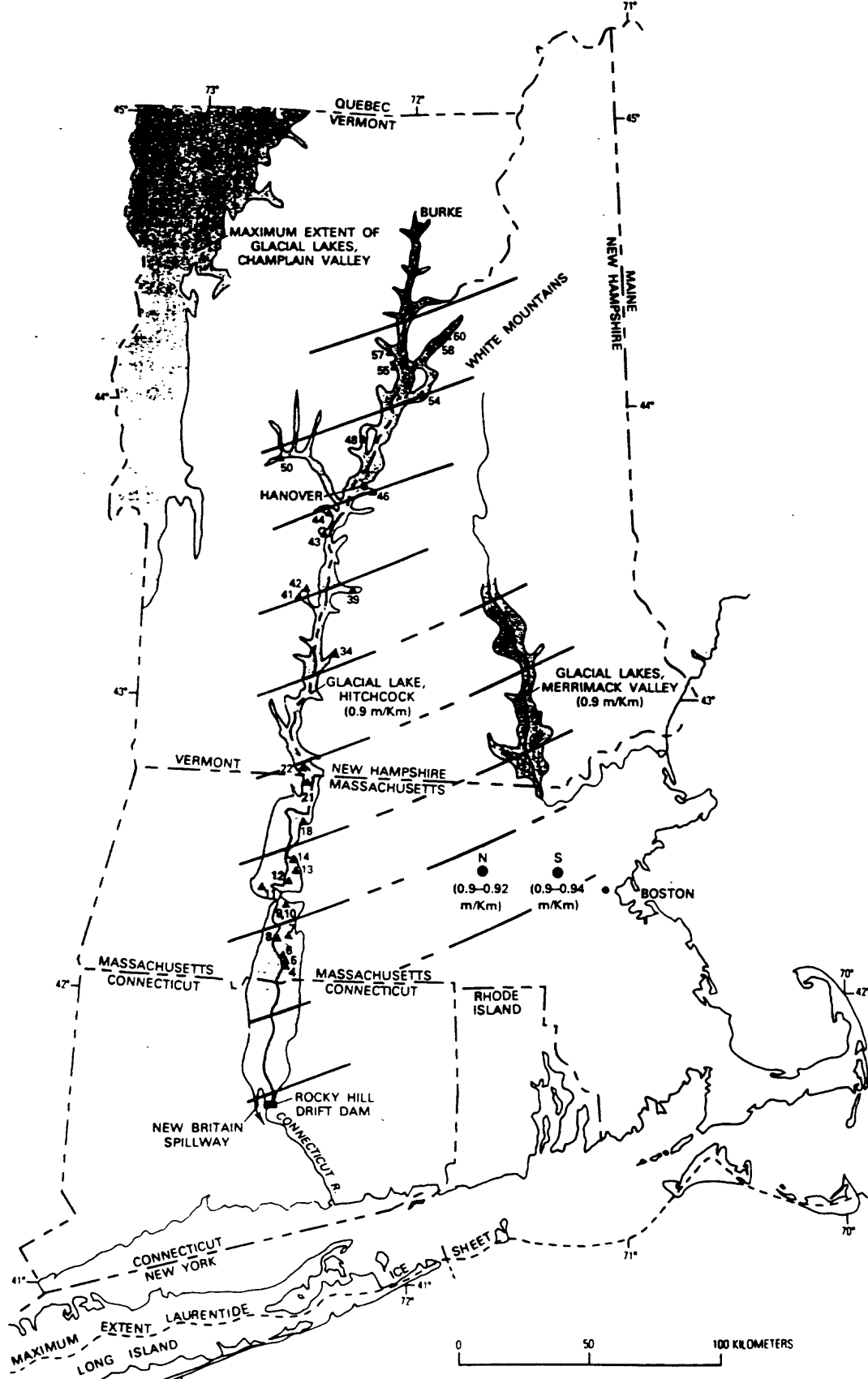
1,040-1,050	Ashby, Mass, 20 miles south of Stop 1 and 7 miles south of next lowest outlet.
1,020-1,030	Along hillside near Ashby-Greenville 7-1/2-minute quadrangle border.
950-960	One-quarter mile east of the next higher outlet.
920-930	On Route 31 in Greenville, just south of quadrangle border.
720-740	Pratt Pond.
640-660	Russell-Abbott State Forest.

### **PISCATAQUOG**

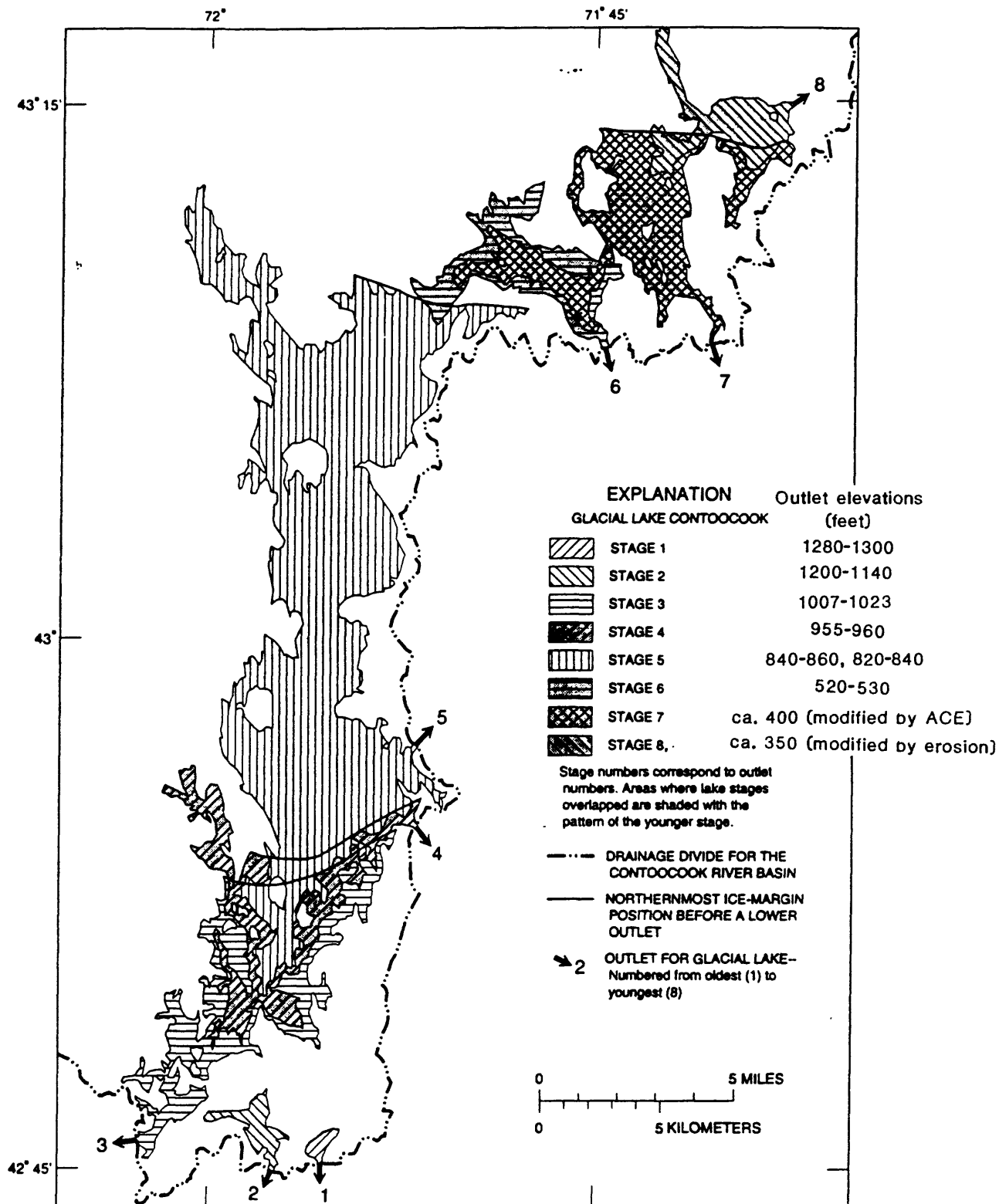
(feet)

670-680	Gorge in Lyndeborough.
580-590	New Boston, north of Joe English Hill.





**Figure 15.** Generalized outline of glacial Lake Hitchcock and other selected glacial lake areas in western New England. Abbreviations: N, glacial Lake Nashua; S, glacial Lake Sudbury. Symbols:  $\blacktriangle^{50}$ , location of elevation obtained from unmodified ice-marginal or meltwater-derived delta used in regression analysis. Uplift isobase interval, 25 meters (82 feet). (Figure taken from Koteff and Larsen, 1989).



**Figure 16.** Successive lake stages and outlets of glacial Lake Contoocook, New Hampshire. Modified from Moore (1995) to show outlet elevations in feet.

## **DISTRIBUTION OF SILT AND CLAY DEPOSITS**

Lithologic logs of wells and borings in the vicinity of several of our field trip stops are in appendix 1, and the distribution of wells and test borings that intersect silt and clay layers within the area of glacial Lake Contoocook is shown in figure 17. Silt and clay deposits (perhaps proximal varves at Stop 1) are found in some deposits of glacial Lake Souhegan, but at this date, a comprehensive compilation of their distribution has not been undertaken by the authors.

The authors have not done extensive field work in the Piscataquog basin, but silt and fine-grained sand are exposed in some pits there. One well log describes 95 feet of silt and some very fine-grained sand (NCAI, fig. 12, appendix 1). Koteff (1970) identified deposits of glacial Lake Piscataquog but did not name the glacial lake; he simply referred to these as New Boston area deposits.

## **MELTWATER EROSIONAL CHANNELS**

Abundant erosional channels in the three basins were carved into previously deposited stratified drift, till, and bedrock. Several bedrock gorges here (certainly Pulpit Rock, Stop 12) indicate that large volumes of meltwater flowed through them. We also see evidence for late glacial erosion of till and stratified drift deposits, especially at Stops 1, 5, and 8. Many of the deep erosional channels are downstream from lake outlets.

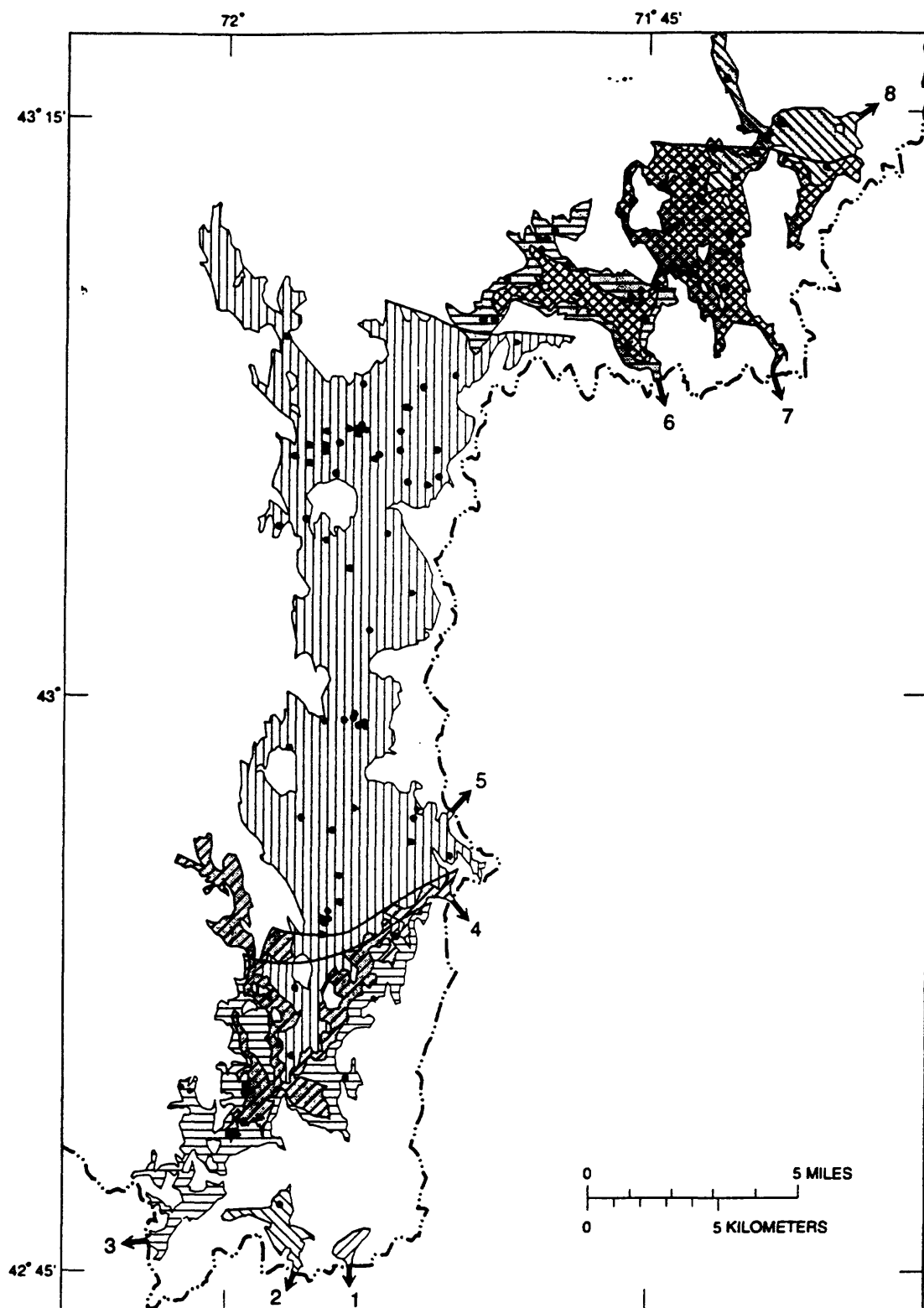
## **BEDROCK GEOLOGY**

The major parts of the Contoocook, Souhegan, and Piscataquog drainage basins are underlain by Silurian and Devonian metasedimentary rocks of the Kearsarge-central Maine synclorium (Lyons and others, 1986). These metasedimentary rocks have been extensively intruded by plutonic rocks of Devonian age. Kinsman Quartz Monzonite of this series contain very distinctive, large white feldspar phenocrysts.

For the most part, the metasedimentary rocks form the mountains, whereas the plutonic rocks are predominant in the basins. The southeastern part of the study area is underlain mostly by Precambrian and Ordovician Massabesic Gneiss, which is partly intruded by Permian plutonic rocks. All of these rocks trend generally northeastward.

## **EVIDENCE FOR GLACIAL READVANCE**

Evidence for glacial readvance was found in at least one site in the study area. The Muzzey Road pit in Francestown (Stop 9) contains sections of highly folded and faulted bedding that is very compact and, in places, is overlain by till. Perhaps this readvance may be correlated with the readvance that has been documented by Stone and Koteff (1979) in the Merrimack valley near Manchester.



**Figure 17.** Distribution of silt and clay in the deposits of glacial Lake Contoocook, New Hampshire (black dots show the locations of wells or borings that penetrated silt and clay). For explanation of stages and outlets, see figure 16.

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## **APPENDIX 1**

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**Appendix 1.** Lithologic logs of wells and borings shown in the figures in the guidebook for 1993 Friends of the Pleistocene Annual Reunion, Concord, N.H

The following descriptions are included to explain the headings and abbreviations used in appendix 1.

**Local site number:** First two characters are U.S. Geological Survey town code. Third character codes are the following: A, boring done for hydrologic purposes; B, boring done for constructional purposes; W, well. The numbers are sequential numbers for each town.

**Depth drilled:** Depth drilled in feet below land-surface datum.

**Depth of well:** Depth of well in feet below land-surface datum.

**Depth to refusal:** Depth to bedrock or refusal in feet below land-surface datum.

**Depth to top:** Depth to top of each lithologic unit, in feet below land-surface datum.

**Depth to bottom:** Depth to bottom of unit, in feet below land-surface datum.

**Aquifer code:** Primary aquifer code of well or boring; codes for geologic ages and materials are listed below.

110SDMN, Quaternary sediment, undifferentiated

112SRFD, Pleistocene stratified drift

112TILL, Pleistocene till

BEDROCK, bedrock

**Lithology:**

The following lithologic codes are used to describe aquifer units:

GRVL, Gravel

GNSS, Gneiss

SDGL, Sand and gravel

SDST, Sand and silt

SGVC, Sand, gravel, and clay

**Abbreviations:**

VF, Very Fine

F, Fine

M, Medium

C, Coarse

VC, Very Coarse



**Table 1:** Lithologic logs of wells and borings shown in the figures in the guidebook for 1993 Friends of the Pleistocene Annual Reunion, Concord, N.H

[--, a dash indicates no data available]

Local site number	Depth drilled (feet)	Depth of well (feet)	Depth to refusal (feet)	Depth to top (feet)	Depth to bottom (feet)	Aquifer code	Lithology
Greenfield							
GSW 5	--	150.0	--	110.0	--	BEDROCK	--
GSW 8	--	185.0	--	70.0	--	BEDROCK	--
GSW 14	--	195.0	--	123.0	--	BEDROCK	--
GSW 15	--	147.0	--	77.0	--	BEDROCK	--
GSW 21	--	192.0	--	95.0	--	BEDROCK	--
GSW 26	--	325.0	--	60.0	--	BEDROCK	--
GSW 28	--	285.0	--	95.0	--	BEDROCK	--
GSW 32	130.0	100.0	--	0 40.0 88.0 120.0	40.0 88.0 120.0	112SRFD 112SRFD 112SRFD 112SRFD	Sand M-C Sand F-C Sand F-C Sand F
GSW 34	--	160.0	--	40.0	--	BEDROCK	--
GSW 36	--	140.0	--	0 26.0	--	110SRFD BEDROCK	SDGL --
GSW 70	--	250.0	--	0 150.0	--	110SDMN	SGVC
GSW 74	98.5	57.0	98.5	0 17.0 33.0 54.0 56.0 93.0 98.5	17.0 33.0 54.0 56.0 93.0 98.5	110SDMN 112SRFD 112SRFD 112SRFD 112SRFD 112TILL BEDROCK	SDGL CS-MS, Cobbles, Pebbles Sand VCS-MS Sand VCS-FS, G, Trace silt Clay Sand, MS-FS, VCS-FG, some silt-clay laminae Till sandy GNSS
GSW 101	47.0		47.0	0 34.0	34.0	112SRFD 112TILL	Sand M-C, Some lenses F or C sand Till
Henniker							
HMB 1	53.0	--	53.0	0 24.0 40.0 45.0	24.0 40.0 45.0	112SRFD 112SRFD 112SRFD 112SRFD	Sand, F, Trace silt Sand, M, some silt Sand F Sand silty
HMB 7	60.0	--	--	0 45.0	45.0 60.0	112SRFD 112TILL	Clay Till
HMW 20	60.0	60.0	--	--	--	--	--

**Table 1:** Lithologic logs of wells and borings shown in the figures in the guidebook for 1993 Friends of the Pleistocene Annual Reunion, Concord, N.H.--Continued

[--, a dash indicates no data available]

Local site number	Depth drilled (feet)	Depth of well (feet)	Depth to refusal (feet)	Depth to top (feet)	Depth to bottom (feet)	Aquifer code	Lithology
Hillsboro							
HOW 26	--	500.0	--	68.0	--	BEDROCK	
HOW 31	--	500.0	--	33.0	--	BEDROCK	
HOW 32	--	355.0	--	20.0	--	BEDROCK	
HOW 46	--	244.0	--	0 50.0	50.0	110SDMN BEDROCK	Sand
New Boston							
NCA 1	97.0			0 95.0 97.0	95.0 97.0	112SRFD 112TILL BEDROCK	Silt, some sand, VF Till
NCA 10	14.0	--	14.0	0 14.0	14.0	112ASRFD 112TILL	SDGL Till
NCW 8	83.0	50.0		0 48.0 55.0 83.0	48.0 55.0 83.0	112SRFD 112SRFD 112SRFD 112TILL	Sand, M, tan with C-VC lenses Sand, M, gray with C-VC lenses Sand, tan with C-VC lenses Till
New Ipswich							
NJA 1	31.0	--	--	0 2.5 7.5 12.5 29.5	2.5 7.5 12.5 29.5 31.0	112SRFD 112SRFD 112SRFD 112SRFD 112TILL	GRVL, cobble gravel SDGL, granule gravel, F-VC sand, poorly sorted, SDGL, granule gravel, VC Sand, some F to M sand, 1-inch round stones SDGL, granule gravel, VC to F sand, well sorted Till, gray, clayey, angular rock frag- ments, refusal at 31 feet
NJA 2	24.0	--	24.0	0 17.0	17.0 24.0	112SRFD 112TILL	SDGL, pebble gravel, cobble gravel Till
NJA 3	37.0	--	--	0 22.0 31.0	22.0 31.0 37.0	112SRFD 112SRFD 112TILL	Sand, F sand, some iron staining SDST, VF sand, silt Till, refusal at 37 feet
NJW 76	--	255.0	--	0 25.0	--	110SDMN BEDROCK	SGVC
NJW 110	--	500.0	--	0 110.0	--	110SDMN BEDROCK	Clay
NJW129	--	205.0	--	0 30.0	--	110SDMN BEDROCK	SDGL

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## **APPENDIX 2**

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## **Appendix 2. GEOHYDROLOGIC SETTING**

By Richard Bridge Moore<sup>1</sup>

Three types of aquifer materials in the study area are (1) stratified drift, which is a major source of ground water for towns and cities and is the focus of this study; (2) till, which locally can supply minor amounts of water for households; and (3) bedrock, which differs in yield from place to place but provides many households with water.

### **Stratified Drift**

Stratified drift consists of stratified, sorted, dominantly coarse-grained sediments (sands and gravels) deposited by glacial meltwater at the time of deglaciation. Included as part of the stratified-drift aquifers (fig. 2.1) are recent alluvial and windblown deposits, as well as deposits redistributed by the rapid drainage of glacial-ice-dammed lakes, in contact with stratified drift. Hydraulic characteristics of these sediments that affect ground-water storage and flow are related to the glaciofluvial environment in which they were deposited. Stratified-drift deposits are composed of distinct layers of sediments with different grain-size distributions sorted according to the depositional environment. For example, swiftly moving meltwater streams deposit coarse-grained sediments with large pore spaces between grains. If saturated, coarse-grained sediments form aquifers that are able to store and readily transmit ground water to wells. As meltwater slows, fine-grained sediments, including fine silts and clays, are deposited in lakes and ponds; these deposits do not readily transmit water to wells.

### **Lakes Dammed by Glacial Ice in the Contoocook Valley During Deglaciation**

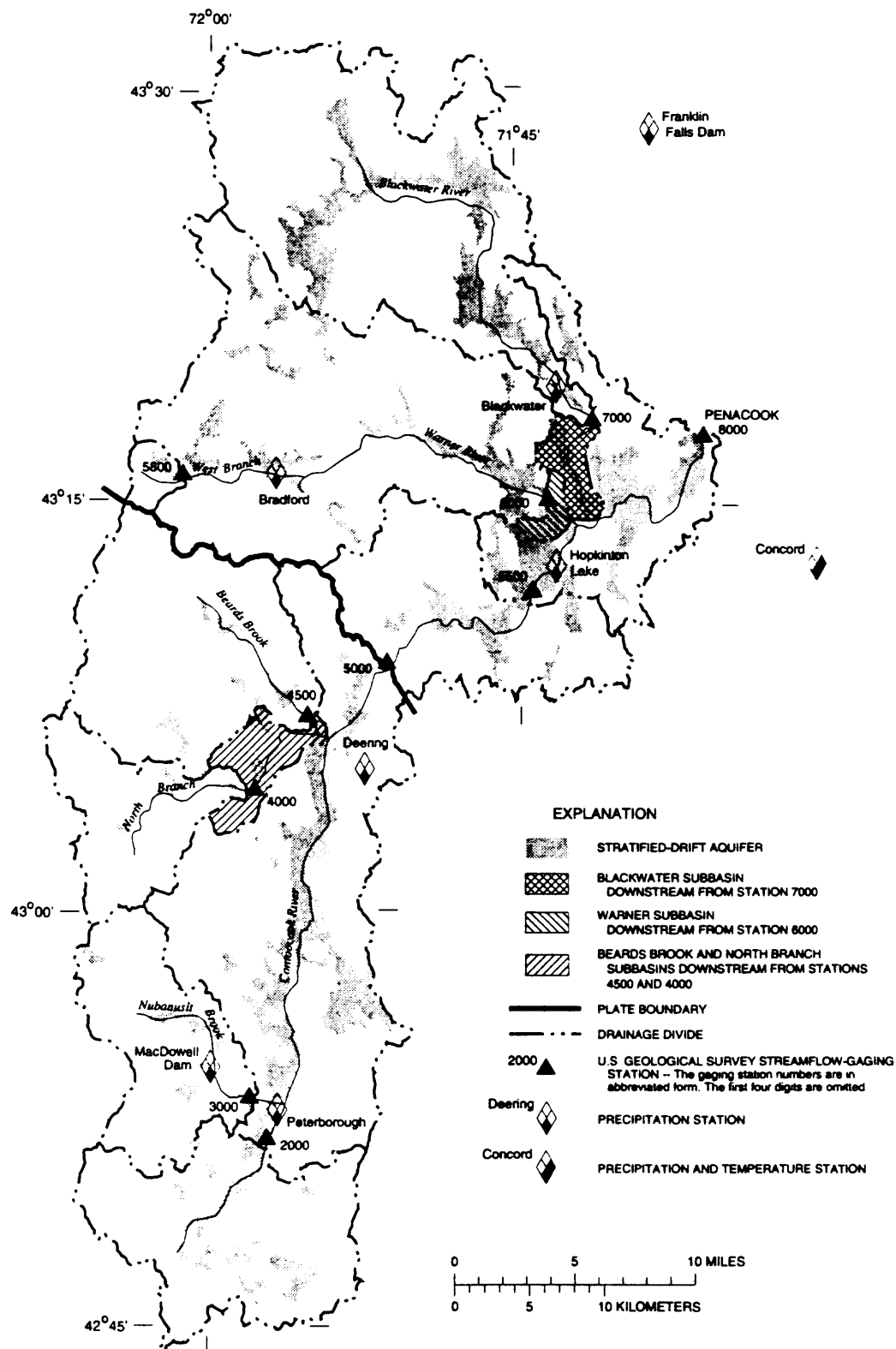
During deglaciation, the natural drainage to the north in the Contoocook River basin was obstructed by the ice margin, and lakes formed (Upham, 1897, p. 11-12). As the ice margin receded to the north, eight progressively lower lake outlets were exposed one by one, and the older lakes were drained rapidly to the levels of the newly exposed outlets.

The surfaces defining previous lake levels of the glacial lakes in the Contoocook River valley have been uplifted in response to the removal of the glacial ice (isostatic rebound), the uplift being greater to the north-northwest. Projections of these previous lake surfaces now dip to the south-southeast. No studies have been made in the Contoocook basin to determine the exact slope of these projected lake surfaces; however, an estimate can be made by looking at adjacent valleys to the east and to the west.

To the west of the Contoocook River basin, in the adjacent Connecticut River valley, a stabilized level of glacial Lake Hitchcock is indicated by 23 ice-contact deltas and numerous other deltas that have not been modified by collapse and have topset-foreset contacts that fall along a single plane. This stable lake level indicates that the postglacial uplift of New England, which resulted from the melting of the continental ice sheet, was delayed by at least 5,000 years (Koteff and Larsen, 1989). This plane, after the postglacial uplift, now dips about 4.8 feet per mile (ft/mi) downward in the direction of about S. 21° E. (Koteff and Larsen, 1989). Likewise, projected lake-level surfaces of glacial lakes to the east in the Merrimack River valley (glacial Lakes Tyngs-

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<sup>1</sup> U.S. Geological Survey



**Figure 2.1.** Location of stratified-drift aquifers, subbasins, streams, streamflow-gaging stations, and climatological stations in the Contoocook River Basin.

boro, Merrimack, and Hooksett) now slope 4.7-4.9 ft/mi downward to the south-southeast (Koteff and others, 1984). From this information, glacial lakes in the Contoocook River basin also are assumed to have had previous lake-level surfaces that now slope about 4.8 ft/mi to the south-southeast.

Areas covered by these glacial-ice-dammed lakes were estimated by projecting, from the outlet surface for each lake, that is 4.8 ft/mi upward to the north-northwest in order to determine where the shoreline would have been; that is, where this projected surface intersects the current land surface. In this process, the northernmost ice-margin position was estimated as the northern shore of each lake. The lakes shown in figure 2.2 represent the maximum possible extent of each lake immediately before it began to drain. Subsequent drainage to a lower lake level resulted from the exposure of a new outlet.

The earliest of the glacial-ice-dammed lakes in the Contoocook River basin were small and formed near the southernmost divide as the active ice margin first began to recede northward through the study area. These small lakes (0.6 mi<sup>2</sup> and 1.8 mi<sup>2</sup>) quickly became filled with sediments as the water escaped out of the basin through outlets 1 and 2 in New Ipswich and Rindge, respectively (fig. 4).

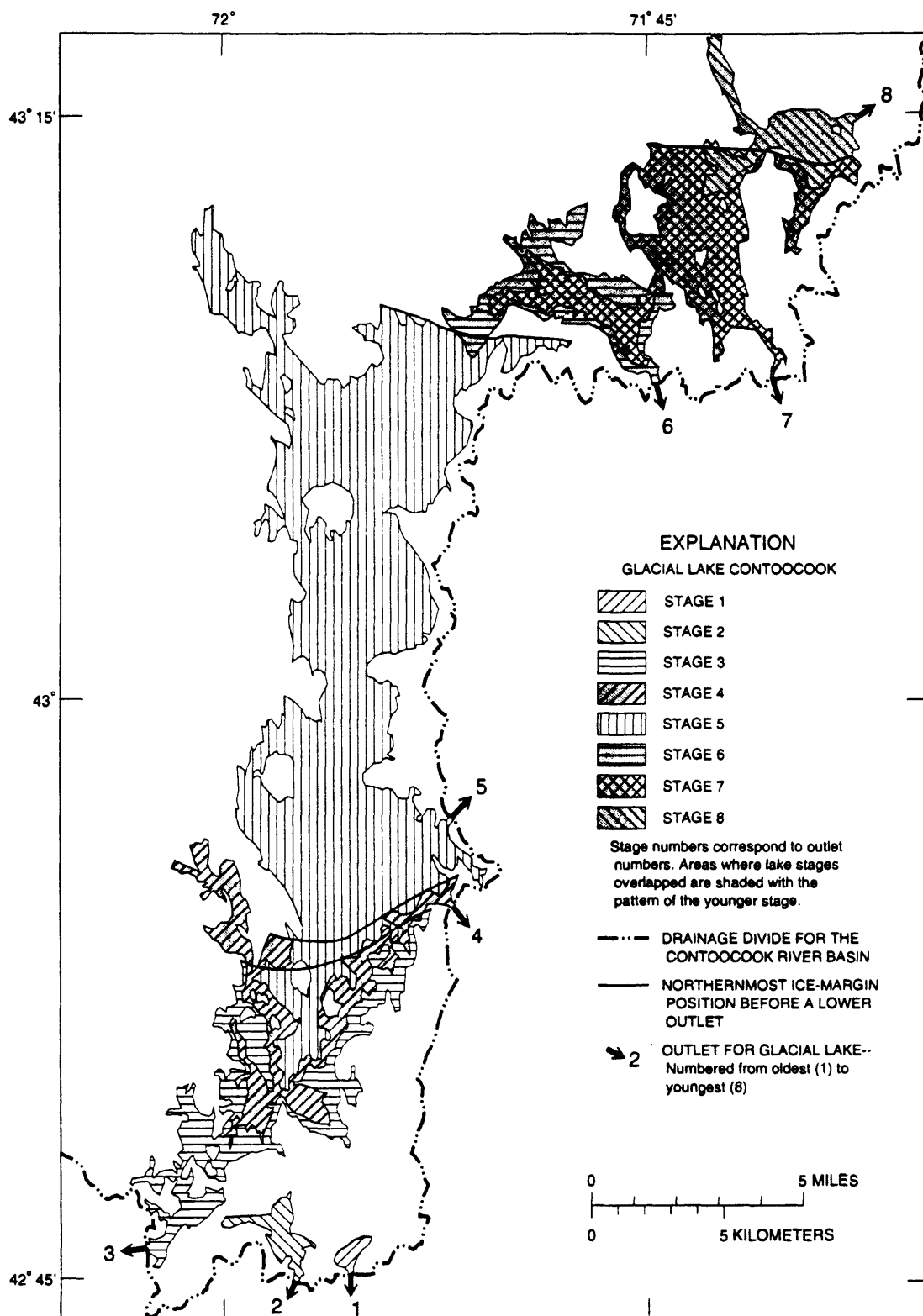
A third glacial lake was slightly lower and formed as outlet 3 was exposed. It must have persisted until the ice margin receded northward and outlet 4 was exposed (fig. 2.2). At its maximum extent, this third glacial lake encompassed about 24 square miles (mi<sup>2</sup>) (less any areas where stagnant glacial-ice blocks may have remained grounded).

The exposure of outlet 4 in Greenfield (fig. 2.2) must have caused the lake level to drop quickly by about 70 feet (ft). Presumably, the deeply eroded V-shaped channel at the outlet, which has been eroded into till and bedrock, was created by rapid drainage of the lake to this temporary base level.

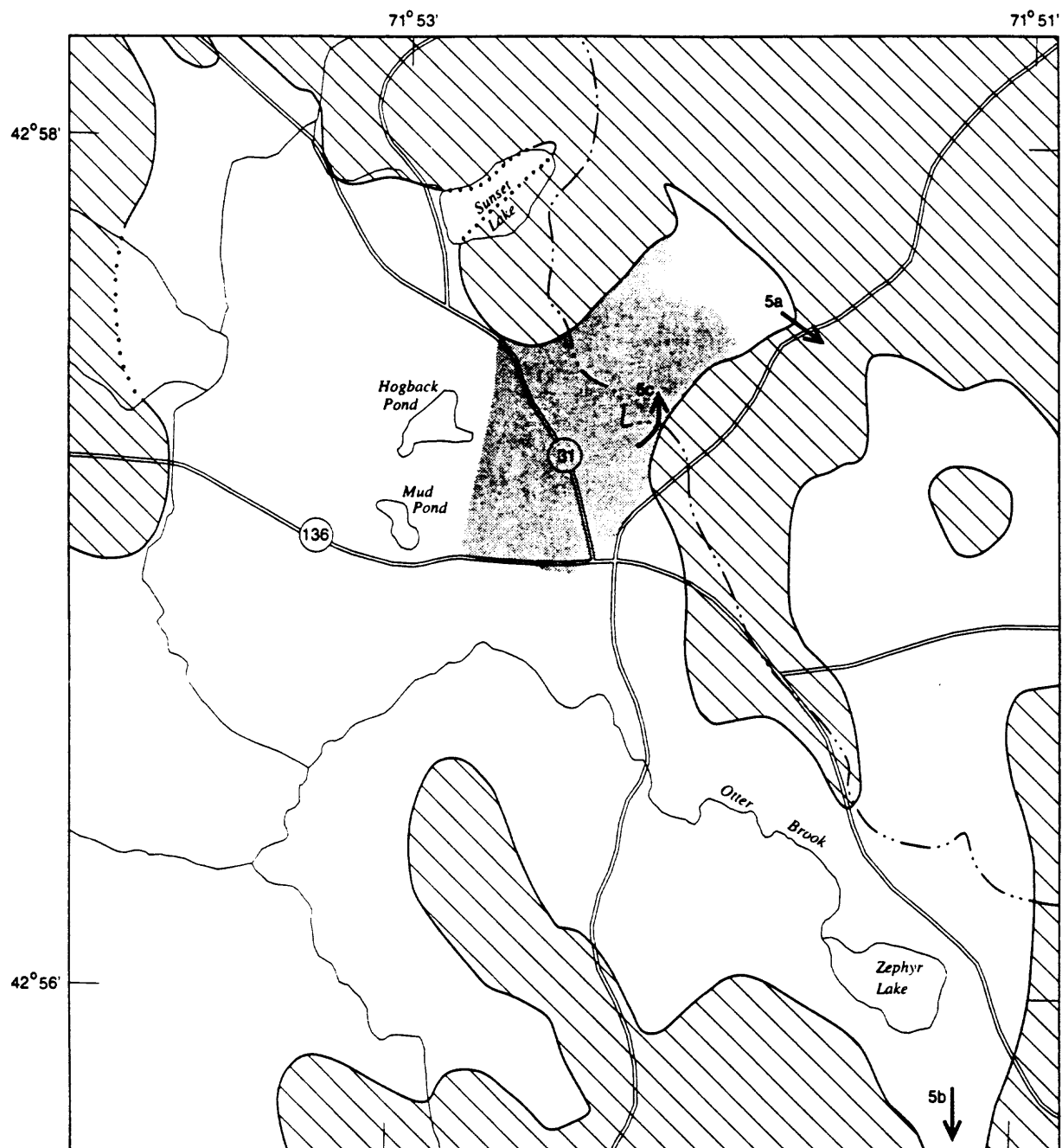
Outlet 4 remained the spillway for the lake until the ice margin retreated a couple of miles north to potential outlets in Greenfield. The lowest point to the north in Greenfield along the existing drainage divide must have become the new control for the lake.

The new, lower outlet in Greenfield, outlet 5, would have drained the lake to a level about 130 ft lower than the previous level at outlet 4. Outlet 5 was complicated in that the drainage shifted from outlet 5a to 5b and finally to 5c (fig. 2.3). Initially, the lake would have had a till- and bedrock-controlled spillway at outlet 5a. Severe erosion is found along Rand Brook below this outlet (Carol Hildreth, Office of the New Hampshire State Geologist, personal commun., 1992). This erosion must have resulted from the lowering of the lake level from outlet 4 to outlet 5a. Following this initial drop in lake level, Rand Brook became blocked, presumably by glacial ice, and the lake rose until outlet 5b (fig. 2.3) controlled the lake level. At that time, as the ice margin was still adjacent to outlet 5a, a delta was deposited across the small bay adjacent to outlet 5a (fig. 2.3). Once Rand Brook again became free of glacial ice, a new spillway (outlet 5c, fig. 2.3) formed between the till shore and the deltaic sand and gravel. As the ice margin receded further northward, this delta-formed spillway remained and controlled the lake level.

Ice-marginal deltas, formed sequentially over a distance of 18 miles (mi) to the north-northwest, were deposited in this lake. Deltas having tops that correspond to a lake controlled by outlet 5 are found in Greenfield, Hancock, Antrim, Hillsboro, and Bradford. These deltaic deposits were deposited in a single, large glacial lake, according to Upham (1897). At its maximum



**Figure 2.2.** History of successive lake stages and outlets of glacial Lake Contoocook.



Base modified from U.S. Geological Survey 1:24,000  
 Peterborough North, N.H. 1987,  
 Greenfield, N.H. 1987. Polyconic projection, Zone 19

0 1,000 2,000 3,000 FEET  
 0 400 800 METERS

#### EXPLANATION

- |                                   |  |
|-----------------------------------|--|
| DELTA DEPOSITED ACROSS OUTLET BAY | CURRENT DRAINAGE DIVIDE FOR CONTOOCCOOK RIVER BASIN                                      |
| STRATIFIED-DRIFT AQUIFER          | BOUNDARY OF STRATIFIED DRIFT-- Dotted where concealed                                    |
| TILL AND BEDROCK                  | OUTLET OF GLACIAL LAKE-- Outlet 5a was the initial outlet followed by outlet 5b then 5c. |

**Figure 2.3.** Outlets for stage 5 of glacial Lake Contoocook.



extent, this lake would have covered about 83 mi<sup>2</sup> (less any area covered by stagnant-ice blocks) as compared to Lake Winnepesaukee that currently (1992) covers 70 mi<sup>2</sup>.

The till and sand-and-gravel spillway in Greenfield remained the outlet to the lake until the ice margin receded about 14 miles directly north and cleared Craney Hill in Henniker. The exposure of a new outlet 6 drained the lake through Weare. Lake levels would have dropped about 390 ft, and the lake would have greatly decreased in areal extent. This small lake, corresponding to outlet 6, would have been about 12 mi<sup>2</sup> (less any areas covered by stagnant-ice blocks) at its maximum extent just before draining.

Evidence of severe erosion downstream from outlet 6 has been observed in the Piscataquog River basin in Goffstown, where stratified drift in the river valley apparently has been removed and only isolated remnant pockets of stratified drift remain (J.E. Cotton and J.D. Ayotte, U.S. Geological Survey, oral commun., 1991). A delta associated with the drainage of the large lake was deposited in the new 12-mi<sup>2</sup> lake. This delta, composed of reworked material, is found on the northern slope of Pats Peak in Henniker. Because of the water-bearing characteristics of this deposit, municipal wells for the town of Henniker were placed in the delta.

Outlet 6 remained the outlet to the lake until outlet 7 (fig. 2.2) was exposed in Weare. This exposure would have been accompanied by another approximately 90-foot drop in lake level, as well as more erosion and redeposition down the Piscataquog River basin.

The channel at outlet 7 has been used and modified in recent years by the U.S. Army Corps of Engineers as an alternative outlet for the Hopkinton-Everett Reservoir. During flooding of the current Contoocook River, water can be redirected down this modified spillway of an old glacial lake. At its maximum extent (just before draining), this glacial lake would have covered about 20 mi<sup>2</sup> (less any areas covered by stagnant-ice blocks).

Outlet 7 remained the outlet to the 20-mi<sup>2</sup> lake until outlet 8 (fig. 2.2) was exposed in Concord and the lake level dropped about 50 ft. This new spillway, composed of till, would have remained the outlet for the lake until it filled in with sediments and the lake level was lowered by erosion of the spillway. The course of the Contoocook River currently passes through what was once the outlet to the final lake that formed in the Contoocook River valley at the end of this long sequence of successively lower glacial lakes. At its maximum extent, this final lake probably covered about 7 mi<sup>2</sup>.

### **Depositional Environment**

The deglaciation process, and the location of glacial lakes during deglaciation, had a pronounced effect in determining the types of stratified-drift aquifers within the study area. Deglaciation was probably a systematic process of retreat with possible minor local readvances (Koteff and others, 1984). The presence of glacial lakes resulted in deltas and other lake deposits.

The primary aquifers in the study area are found in areas of former glacial-ice-dammed lakes. The aquifers consist of the ice-contact deltas, other deltas, eskers, and redistributed sediments resulting from the rapid draining of the lakes and, perhaps, by postglacial processes (fig. 2.2). The coarsest stratified-drift deposits in these areas are ice-contact deltas and eskers. Some of the deltas appear to have been fed by meltwater coming from esker tunnels within the ice. Deltas associated with feeder eskers are found in Hopkinton, Hancock, Greenfield, and New Ipswich.

Narrow valleys within the bedrock surface, buried beneath parts of many of these ice-contact deltas, are found in Hancock and Peterborough. These valleys may have been caused by erosion of the bedrock surface by glacial ice or subglacial meltwater before the deposition of the deltas. Saturated thicknesses are considerable at well sites above these valleys.

In the valleys in the northern part of the study area, drainage typically would not have been obstructed by the ice margin. Only small lakes would have formed there, where meltwater flowing from the glacier was dammed by till or bedrock, or where small northward-draining valleys were ice dammed. The largest of the lakes not held in by ice was in the area draining to outlet 8 (fig. 2.2). Above the areas inundated by glacial lakes, deglaciation resulted in morphosequences with eskers, kames, and outwash deposits, some of which grade into lake deposits. Examples of these types of aquifers are found in Warner, Bradford, Sutton, New London, and Andover.

Eskers are long ridges of sand and gravel deposited in the meltwater channels within the zone of ice stagnation during deglaciation. Eskers are found in Henniker, Hopkinton, Hillsboro, Hancock, Greenfield, Bennington, and New Ipswich. Where there is a significant saturated thickness, eskers commonly are good aquifers. Eskers and kames are also commonly found within areas inundated by the glacial lakes. Kames are low mounds, knobs, hummocks or short irregular ridges of sand and gravel deposited by glacial meltwater; the precise mode of formation is uncertain. Kames are located throughout the study area. Outwash consists of stratified deposits chiefly of sand and gravel removed or "washed out" from a glacier by meltwater streams and deposited beyond the margin of a glacier; usually in gently sloping outwash surfaces. Outwash surfaces include areas in Warner, Webster, Bradford, Andover, and New London.

### **Till**

Till—an unsorted mixture of clay, silt, sand, gravel, and rock fragments—is deposited directly by glacial ice. In the study area, till is discontinuous on the bedrock surface and is generally thin. The types of till commonly found in the study area are an upper, brownish, presumably oxidized till, underlain by a compact grayish till. The upper brownish till in many localities is an ablation till composed of loosely consolidated rock debris formerly carried by glacial ice. Ablation tills accumulated as glacial ice was removed by ablation. The lower compact till in many localities is a lodgement till, originally deposited beneath the moving glacial ice. The thickest sequences of till are composed of lodgement till in drumlins. Generally in New Hampshire, till lies directly on bedrock.

Till generally is considered to be a minor source of ground water because of its low transmissivity. Large-diameter dug wells in till can provide modest amounts of water for household needs, but water-level fluctuations within till can be quite large, and dug wells can dry up during dry seasons. Ablation tills containing lenses of stratified sand and gravel are the most productive till deposits. Because sorted stratified drift and ablation tills can grade into one another, the distinction between the two material types is not always clear.

### **Bedrock**

The Contoocook River basin is underlain by bedrock associated with the Kearsarge-Central Maine Synclinorium (Lyons and others, 1986). This major structural belt trends generally north-northeast to south-southwest. The synclinorium contains metamorphic rocks of Devonian and

Silurian age. Also included are younger Devonian plutonic rocks of the New Hampshire Plutonic Series (Billings, 1956).

Ground water is found in fractures within these rocks. The capacity of the bedrock to store and transmit ground water is limited by the number, size, and degree of fracture interconnection. Wells that tap bedrock commonly yield small supplies of water that are generally adequate for individual households. In areas where the bedrock is extensively fractured, high yields can be obtained. Six municipalities in New Hampshire, all outside the study area, have wells in crystalline bedrock that yield 0.5 million gallons per day (Mgal/d) or more (U.S. Geological Survey, 1985). Within the study area, yield data stored in the GWSI data base from 1,585 wells finished in bedrock, ranged from 0 to 200 gallons per minute (gal/min) (0.29 Mgal/d) at well ANW-37. Only 15 of these wells have yields greater than or equal to 100 gal/min (0.14 Mgal/d).